FUNCTIONAL OUTCOMES OF RADIAL HEAD ARTHROPLASTY

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Submitted By

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Dedicated

to

my Family

&

Teachers

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Firstly, I humbly thank the God Almighty for giving me strength & carrying me in all times.

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Dr. Shikhar Bindal

LIST OF ABBREVIATIONS

ADL	Activities of daily living
AO/OTA	AO Foundation/Orthopedic Trauma Association
AP	Anteroposterior
CT	Computed tomography
DASH	Disabilities of Arm, Shoulder and Hand
DRFs	Distal radius fractures
DRUJ	Distal radioulnar joint
FOOSH	Fall Over Outstretched Hand
HO	Heterotopic Ossification
LCL	Lateral collateral ligament
LUCL	Lateral ulnar collateral ligament
MCL	Medial collateral ligament
MEPI	Mayo Elbow Performance Index
MEPS	Mayo Elbow Performance Score
MRI	Magnetic resonance imaging
NSAIDs	Non-steroidal anti-inflammatory drug
OA	Osteoarthritis
ORIF	Open reduction and internal fixation
PLC	Posterolateral corner
PREE	Patient rated Elbow Evaluation
RHA	Radial head arthroplasty
RHP	Radial head prosthesis
RHR	Radial head resection
RTA	Road traffic accident
SD	Standard deviation
SPSS	Statistical Package for Social Sciences
UCL	Ulnar collateral ligament
USG	Ultrasonography
VAS	Visual analogue scale

ABSTRACT

Introduction : ORIF techniques are challenging to treat comminuted fractures of the radial head. Thus, radial head arthroplasty has been promoted for the treatment of unreconstructible radial head fractures with associated bony and ligamentous injuries, as well as for the management of complications following unsuccessful internal fixation or radial head excision. The results of this procedure compare favorably with those reported after open reduction and internal fixation.

Aim of Study: To evaluate the functional outcomes of radial head replacement in patients above 18 years of age, with Mason type III and type IV radial head fractures in the immediate post-operative period as well as at 3 months and 6 months.

Materials & Methods: 26 patients scheduled to undergo radial head arthroplasty in Dayanand Medical College & Hospital, Ludhiana from 1st January 2021 to 31st August 2023 were evaluated based on elbow flexion, elbow extension deficit, supination, pronation, post operative complications and MEPS scores, in the immediate post-operative period, and then 3 months and 6 months to analyse functional outcomes

Results: MEPS at 6 months follow up for 4 cases (15.38%) had good scores, and 22 cases (84.62%) had excellent scores, with a mean ± SD of 97.31 ± 6.67. Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$). None of the patients had elbow instability after radial head replacement and 22 cases (84.62%) had no complications, while 3 cases (11.54%) had a stiff elbow, and 1 case (3.85%) had heterotopic ossification

Conclusion: Radial head arthroplasty effectively restored the stability and congruency of the elbows with radial head fractures. There was a significant improvement in the range of motion involving flexion, extension deficit, supination and pronation during our follow up period with minimal complications. There was also a significant improvement in pain levels, ADL and MEPS scores during follow up of immediate post op, 3 months and 6 months – indicating improved quality of life after the surgery.

Keywords: Functional Outcomes, elbow fractures, elbow dislocation, radial head fractures, Radial head arthroplasty, radial head replacement, MEPS, Mason type, elbow flexion, extension deficit, supination, pronation.

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INTRODUCTION

Elbow fractures make up about 5% of all fractures, with radial head fractures comprising approximately one-third of these cases, significantly impacting elbow injuries. Given the relatively high incidence and the average age of affected patients being 45, this condition can adversely affect a considerable portion of the young and active population.[1]

Radial head injuries range from minimal displacement to large, comminuted fractures with accompanying bone and ligament injuries. These injuries often result from an application of axial load to the forearm, causing the "radial head to impact the capitellum of the humerus, such as during a fall on an outstretched hand". The treatment varies on the severity of these fractures from minimal treatment to surgical intervention, excision, or replacement.[1-3]

There are two classification systems for classifying radial head fractures: "Mason classification and the newer AO classification system". In the Mason classification, Type I fractures include "non-displaced or minimally displaced fractures of the radial head and neck that do not require operative treatment". Type II fractures include "displaced fractures of the head and neck that are amenable to open reduction and internal fixation (ORIF)". Type III fractures include "severely comminuted fractures of the head and neck that require prosthetic replacement or excision. And type IV fractures include fracture of the radial head with associated dislocation of the elbow joint also requiring prosthetic replacement".[2]

Another classification is the AO classification system which classifies fractures of the proximal radius and ulna into 3 types: "Type A includes extra-articular fractures of one or both bones of the forearm. Type B includes intra-articular fractures of one bone with or without an extra-articular fracture of the other bone. Type C includes intra-articular

fractures of both bones. The fractures are then further subdivided into groups 1, 2 and 3 based on the involvement of the radius, the ulna or both the radius and ulna, and the location of the fracture line. They are then further subdivided into subgroups 0.1, 0.2 or 0.3 based on further specific qualifications like degree of fragmentation and the complexity of articular and/or metaphyseal involvement".[3]

The primary treatment for such fractures is open reduction internal fixation also known as ORIF. It is very effective in reducing the fractures and joining the bone, especially in cases of displaced fractures of radial head with a simple pattern. However, in case of comminuted fractures, the complications rate may be high enough and the procedure may become unsuccessful.[4,5,6] Radial head arthroplasty also known as RHA is an alternate to ORIF with comparable results in terms of efficacy with minimal complications.[7] Compared to the past treatment where excision of the radial head was performed for displacement of the radial head fractures, in today's world RHA has become popular in view of the complications such as instability of the valgus elbow, stiffness of the elbow and proximal migration of the bone in cases of the former treatment.[8] Nowadays, RHA forms the primary treatment for a variety of fractures of radial head which may even be accompanied by other injuries of ligament or bone. Also, for patients who have complications or failure of the primary treatment of ORIF, RHA becomes the primary cornerstone for the treatment.[9,10]

Most studies on radial head replacement involve a diverse group of patients, varying treatments, and different outcome measures[11,12] and limited studies were conducted about radial head replacement outcomes in Indian population.

Thus, we conducted this study to assess the functional outcomes in the immediate post-operative period as well as at 3 months and 6 months in patients undergoing radial head replacement.

NEED FOR THE STUDY

The surgical treatment of “comminuted radial head fractures (modified Mason types III and IV)” presents significant challenges and remains a topic of debate. Options include “ORIF, radial head resection (RHR), and RHA”, with no clear consensus on the best approach.[13] Previous “systematic reviews and meta-analyses” have assessed the outcomes of ORIF and RHA. One meta-analysis found that the optimal surgical method for radial head and neck fractures depends on the Mason classification (ORIF for type II and RHA for types III and IV).[14] Majority of the meta-analyses indicate that RHA offers better elbow function and fewer complications compared to ORIF for “Mason type III fractures” in the short term. However, the quality of this evidence is low, and many studies on radial head replacement involve a diverse group of patients, various treatments, and different outcome measures.[15,16] These studies often do not distinguish between “acute or delayed treatment, isolated radial head fractures versus those with associated injuries, or the use of different types of implants”. Further, limited studies have been conducted about radial head replacement outcomes in Indian population.

Selecting the optimal treatment for “Mason type III and IV radial head fractures” requires evaluating multiple factors. These factors include the “stability of the fracture, the degree of displacement, the extent of articular involvement, and the presence of any associated injuries to the forearm or elbow”. While classification systems can inform treatment decisions, they should not be the sole determinant.

The “Mason classification system” aims to categorize treatment options, though “Mason type III fracture” treatments remain contentious. Non-operative treatments often lead to poor outcomes. Fragment excision is seldom recommended; however, if fragments constitute less than 25% of the radial head's surface area and elbow stability is maintained, removal without replacement is possible. For “Mason type III fractures where reduction and internal fixation are

impractical, radial head replacement” is suggested. Fractures with three or more fragments treated with ORIF may result in “unpredictable ulno-humeral and forearm motion, fixation failure, fragment nonunion, and osteonecrosis”.[17,18]

Using “metal radial head prosthesis” to stabilize the elbow is attractive due to the frequent failure of internal fixation in multi-fragmented and displaced fractures of the radial head. Controversy persists regarding the treatment of “Mason type III fractures”. Radial head replacement has been associated with “enhanced patient satisfaction, reduced complications, and superior outcomes compared to ORIF”.[18]

The present study results aim to provide the data of the follow-up outcomes of up to 6 months for the patients undergoing RHA with a modular metallic prosthesis for irreparable radial head fractures”. Since it involves functional outcomes in Indian populations it will help provide data on the implications of radial head replacement and subsequently help improve in the refinement of surgical strategies for radial head fractures specific to the Indian population.

AIMS AND OBJECTIVES

Aims

To evaluate the functional outcomes of radial head replacement, in patients above 18 years of age, with Mason type III and Mason type IV radial head fractures, admitted to Dayanand Medical College and Hospital. It will be a retrospective and prospective, hospital-based study in which patients will be evaluated from 1st January 2021 to 31st August 2023. Retrospectively, from 1st January 2021 to 28th February 2022 and prospectively, from 1st March 2022 to 31st August 2023.

All the patients scheduled to undergo radial head replacement as per inclusion and exclusion criteria will be included in the study.

Objectives:

To evaluate the functional outcomes of radial head replacement in the immediate post operative period as well as at 3 and 6 months by using outcome measurements-

- MEPS (Mayo Elbow Performance Score)
- Elbow flexion
- Elbow extension deficit
- Supination and pronation

REVIEW OF LITERATURE

In the last thirty years, our evolving knowledge of the elbow has deepened our understanding of this “intricate diarthrodial joint”. The radial head, integral to the elbow's stability, interacts synergistically with its surrounding soft tissues and bony framework. It plays a crucial role in maintaining the joint's stable yet fluid motion. Additionally, the radial head is vital in elbow mechanics, bearing up to 90% of the force transmitted across the joint and serving as “a significant secondary stabilizer against valgus forces”.[1]

Radial head anatomy

The “lateral compartment of the elbow” contains the “radial head”. Together with the capitellum, it articulates to produce “the humero-radial joint”. The “proximal radio-ulnar joint” is also formed by the articulation of radial head's circumference with ulna's radial notch. Lastly, a crucial part of “the forearm scaffold is the radial head”. Instead of being round, “radial head” is ellipsoid, conical, and grows larger from proximally to distally.[10]

In neutral rotation, the “longest axis (20 to 23 mm on average) is perpendicular to the ulna's radial notch. Consequently, while the forearm is in supination, the annular ligament that surrounds the radial head becomes loose. The radius's neck, which is around 13 mm long, makes a 17° angle with the radial shaft”.[10]

The “metaphyseal arterial branches” provide “radial head” with majority of its blood supply, which is distributed peripherally. This arrangement of arteries, known as a terminal network, is linked to a higher risk of non-union and post-traumatic necrosis. “Trabeculae that converge towards the radial (bicipital) tuberosity serve as reinforcement for the medial cortex. Consequently, lateral depression of the epiphysis and metaphysis” is frequently caused by traumatic force exerted in valgus.[10]

RADIAL HEAD FRACTURES

Incidence/ prevalence

Radial head acts as significant secondary stabilizer of elbow.[19] One-thirds of elbow fractures and 1-4 percent of all adult fractures are radial head fractures.9 About 20% of elbow injuries result in “radial head fractures”, which usually occur following fall on an outstretched hand with the “wrist extended and the forearm pronated”.[10]

According to a recent study that analyzed data of 42 articles, “incidence of radial head fractures” was 2.5 per 10,000 per year that represented 1.7-5.4% of all fractures. With mean age of 45 years, the injury primarily affects middle-aged and female patients. In children, fractures of the head, neck, and radius can account for as much as 14% of the total elbow fractures.[20]

In a study by Klug et al,[21] with a frequency of 1.7-5.4% of total fractures as well as approximately one-third of elbow fractures, “radial head fractures” are among the most common fractures in adults. Patients between the ages of 20 and 60 have been found to have fractures most frequently, with a male-to-female ratio ranging from 1:2 to 1:1.

Stirling P et al[22] (2021) studied “incidence of radial head replacement” for period of 22 years and reported that there were 615 replacements, with overall incidence being 0.65/100,000/year.

Williams R et al[23] (2019) reported that out of 11,309 proximal radius fractures, 9,694(85.7%) were “radial head fractures”.

Causes

Radial head fractures are possible alone or “in conjunction with other injuries” to the forearm and elbow, such as fracture-dislocations, fractures, and ligamentous injury.[24]

Symptoms

An indirect trauma resulting from a fall onto an extended hand (FOOSH injury), with the “elbow extended, and the forearm pronated”, is

frequently the reason of “radial head fractures”. It is important to feel the elbow's bone landmarks, including the “radial head, medial and lateral epicondyles, and olecranon”, even with the elbow's widespread edema. An elbow dislocation is part of triad injury “(radial head fracture, coronoid fracture, and postero-lateral dislocation of the elbow)” or may occur in conjunction with “fracture of both forearm bones when there is a marked posterior prominence of the olecranon”. When identifying concurrent lesions among individuals having radial head fractures, caution should be used. Thus, oedema and pain in “forearm and wrist” indicate damage to interosseous membrane, while apparent medial bruising could suggest “injury to the ulnar collateral ligament” (Essex-Lopresti fracture).[10]

Classification

Mason created the first generally recognized classification system in 1954 using data from 100 “radial head fractures” which were either non-operatively or surgically treated and then re-examined more than two years later.[25] “Type I, non-displaced marginal fissure or fracture; Type II, displaced marginal fracture with separation or impaction; and Type III, displaced comminuted fracture including the entire radial head”, were identified as the three different types of fractures that call for various treatment strategies (fig. 1). Afterwards, “Broberg and Morrey added a type IV”, which was described as an elbow dislocation plus “radial head fracture”.[26] Mason's categorization was altered by Hochkiss, who included several “clinical criteria”. “Type II refers to a displaced fracture of the neck or radial head” accompanied by loss of joint congruity or a mechanical obstruction of joint mobility. “Comminution, which prohibits internal fixation and necessitates either resection or prosthetic replacement of the radial head”, is the defining characteristic of Type III, as shown in Table 1.[27]

These classifications “poor intra-observer and inter-observer reproducibility” is the limitations associated with them. Their inability to account for “concurrent lesions”, occurring in about 80% of the multi-

fragment fractures, is another major shortcoming (especially “Type III fractures”). In contrast, the “Mayo Clinic classification” merits favor since it considers all concurrent lesions (Fig. 2). [28] Mason's categorization for radial head fractures is followed, with additional letters added to denote concurrent lesions (lower case otherwise, “upper case” if lesion is treated). A “Type III Lcm fracture, for example, is a Mason Type III fracture of the radial head that has three components: an untreated coronoid fracture (c), an untreated tear in ulnar collateral ligament (m), and a repaired tear in radial collateral ligament (L)”.[10]

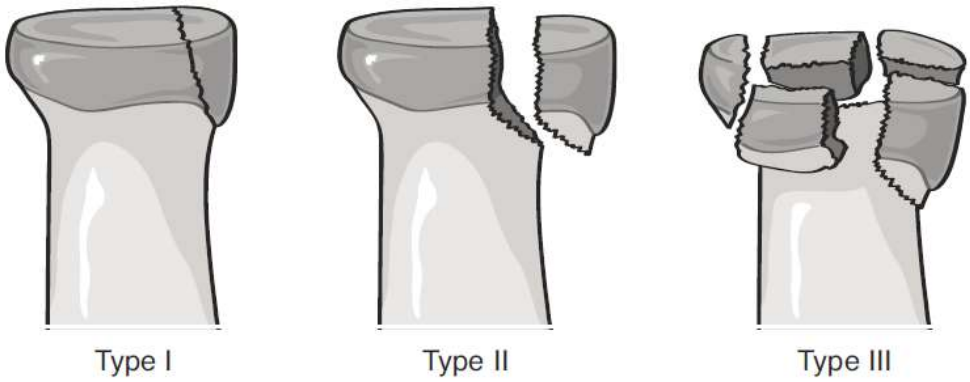
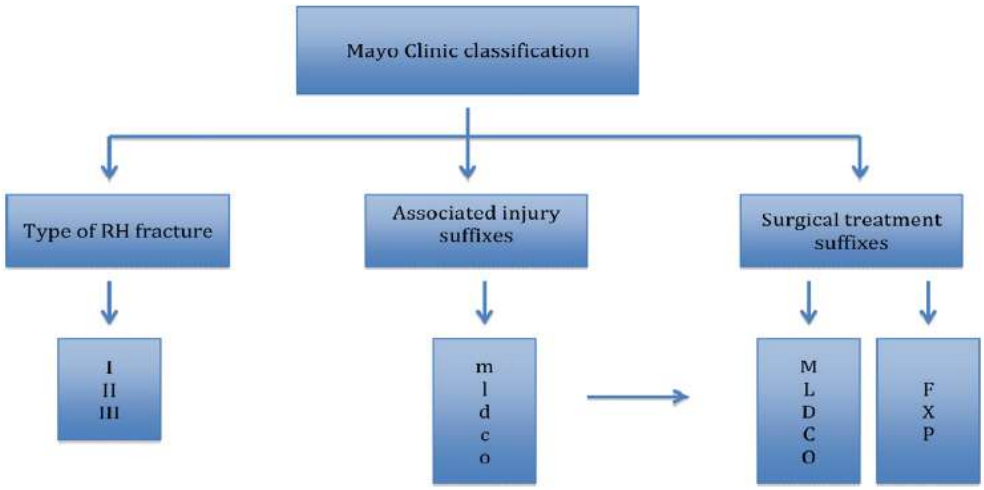


Figure 1: classification by Mason



Type I, non-displaced fracture; Type II, displaced fracture (>2 mm); Type III, comminuted fracture; m, medial collateral ligament; l, lateral collateral ligament; d, distal radio-ulnar disruption; c, coronoid fracture; o, olecranon fracture; F, fixation; X, excision; P, radial head prosthesis

Figure 2: Mayo clinic classification[10]

Table 1: “Mason classification as modified” by Hotchkiss[27]

Type I	“Fracture of the radial head or neck, with little or no displacement Range of pronation/supination limited only by pain and oedema Articular fracture < 2 mm or marginal fracture of the radial head”
Type II	Displaced fracture “(> 2 mm) or fracture of the neck with angulation” “Motion range limitation due to mechanical impingements or loss of joint congruity” “No severe comminution (internal fixation feasible)”
Type III	“Severe comminuted fracture of the radial head or neck” “Reconstruction not feasible according to criteria assessed intra-operatively or radiologically” “Excision required to restore range of motion”

AO classification

In 1987, the Müller AO published their initial distal radius fractures (DRFs) as a component of their general system of classification for long bone fractures. [29] This classification known as the "AO/OTA Classification of Fractures and Dislocations," was accepted as the standard by the Orthopaedic Trauma Association in 2007.[30] Its initial purposes were measuring the severity of injuries, giving information for treatment planning, and assisting with scientific communication. In clinical research today, it is still one of the most popular DRF classification system. Fractures are categorized into three categories (A, B, and C), nine groups (1, 2, and 3), and twenty-seven subgroups (0.1, 0.2, and 0.3) in the original version.[31]. The most popular version is the shortened version that has nine categories (type and group). The

agreement between observers in this method varies; for example, the interobserver kappa for fracture types ranges from 0.37 to 0.68.4 5.[32]

Associated injuries with radial head fractures (RHF)

Associated Elbow Dislocations

The rate of incidence of elbow dislocations remains at “5.21 per 100,000 person-years. Of all elbow dislocations, 18–45% are likely to be terrible triad injuries, which include a combination of elbow dislocation, radial head fracture, and coronoid process fracture”. Elbow dislocations can be classified “as simple or complex. Simple dislocations are typically posterior and involve peri-articular avulsions less than 2 mm, without associated fractures; while Complex dislocations occur in combination with fractures of the radius, humerus, or ulna at the ipsilateral elbow joint”.[33]

The clinical presentation in patients with a dislocated elbow includes “pain, swelling, deformity, and an inability to flex or extend the elbow. Bruising on the medial or lateral side may indicate a ligamentous injury. It is crucial to identify any associated neurovascular deficits and open injuries. Plain radiographs of the elbow in anteroposterior and lateral views are typically diagnostic and can reveal any additional fractures. A CT scan, especially with 3D views, is extremely helpful for evaluating associated fractures. In an acute setting, USG and MRI scans may have limited use”.[33]

The elbow joint is frequently dislocated in the human body. It includes two collateral ligaments: the “medial collateral ligament (MCL, also called the “ulnar collateral ligament” or UCL) as well as lateral collateral ligament (LCL)”.[34]

Medial collateral ligament injuries: The incidence rate of MCL/UCL injuries is reported as “0.29 per 10,000 athlete exposures.[35] Plain film radiography of the elbow is recommended whenever there is a

suspicion of a medial elbow injury. These radiographs are particularly crucial in cases of traumatic, non-throwing injuries to rule out fractures. They also help assess the elbow joint space, detect loose bodies, and identify cartilage lesions. UCL injuries are typically diagnosed by MRI, which is the gold standard. T-2 weighted MRI sequences are particularly helpful as they can reveal fiber discontinuity, increased signal intensity in the injured area, and ligament retraction or distraction. The anterior band of the UCL is best visualized on coronal sequences".[36]

Most of the time, nonoperative treatment is an option for partial UCL tears (grades 1 and 2). After nonoperative treatment has been unsuccessful, athletes are considered for operative management of their injuries. UCL repair and UCL reconstruction are also surgical options that can be considered. Reconstruction with autograft is often the treatment that is recommended more frequently. "Modified Jobe and docking techniques" are the two primary current surgical procedures that are utilized for the reconstruction of the UCL.[36]

Lateral collateral ligament injuries: A complicated capsuloligamentous structure, the "lateral collateral ligament (LCL) off the elbow is essential for maintaining the stability of the radio-capitellar and ulno-humeral articulations. When a supination tension is applied to the forearm due to an LCL injury, elbow instability may occur, causing the proximal radius and ulna to externally rotate away from the humerus. The most frequent cause of LCL injury is elbow dislocation, which is followed by iatrogenic injury. Although uncommon, LCL disease that causes late recurrent instability can be debilitating. A strong index of suspicion, a thorough medical history, and targeted physical examination techniques are needed for the diagnosis. Usually, the LCL complex avulses from its humeral origin in traumatic causes. Non-absorbable sutures are usually inserted into the exposed area or the site of the ligament's avulsion at the humeral origin using bone anchors as part of repair procedures."[37]

Associated fractures of coronoid and olecranon

Coronoid fractures: Among the bone structures that is susceptible to fracture is the ulna's coronoid process, which is crucial for the stability of elbows following dislocation. A comparatively uncommon injury, coronoid fractures affect between 2% and 15% of patients who have dislocation. They frequently occur in an injury known as the “terrible triad of the elbow”, which consists of a “fracture to the radial head, posterior or posterolateral elbow dislocation, and coronoid process fracture”.[38]

Defer assessing the elbow's “range of motion” if it appears to be deformed upon inspection. It is crucial to do neurovascular testing. It is important to evaluate "2-point discrimination and light touch" carefully. Before doing any manipulation, get plain radiographs for look for fractures and dislocations. CT or MRI can be used when plain radiographs are inconclusive. While MRI produces a better identification of soft tissues, CT provides better bony definition.[38]

Managing coronoid fractures in conjunction with “elbow dislocations” is challenging. “Simple dislocations without fractures” typically respond well to “closed reduction, brief splinting, and gentle mobilization”. A similar approach can be effective for “isolated, un-displaced fractures”. However, fractures associated with "triad injuries" generally necessitate surgical intervention.[38]

Olecranon fractures represent “10% of all elbow fractures and typically result from low-energy injuries. The most common type of injury is a displaced fracture with a stable ulno-humeral joint.[39]Diagnosing upper extremity injury starts with complete physical examination, comprising observation, palpation, and complete neurovascular assessment. Standard AP and lateral radiographs of the elbow are usually sufficient to identify isolated olecranon fractures. These radiographs need careful examination for signs of coronoid process fractures, elbow dislocation, and radial head injuries. Advanced imaging is rarely needed for isolated olecranon fractures. Treatment options include immobilization, surgical reduction, and

fixation using tension-band wiring or plate osteosynthesis, as well as excision of the proximal fragment with triceps advancement".[40]

Diagnostic tests

For an appropriate diagnosis, in addition to "a radial head-capitellum view—a modified lateral view in which tube is oriented 45 degrees toward radial head, according to Greenspan—standard radiographs of elbow in antero-posterior and lateral projections should be taken".[41] Careful observation is needed to "identify any concurrent lesions, like a coronoid or olecranon fracture. On routine radiographs, the fracture's displacement and comminution are frequently underestimated. A more precise assessment is offered by computed tomography (CT). To determine the radio-ulnar index (ulnar variance), antero-posterior radiographs of the wrist, or ideally of both wrists, are utilized. An ascension of the radius associated with an Essex-Lopresti fracture is indicated by a positive index where the ulnar surface projects farther. This diagnosis is further supported by the wrist pain and/or oedema, as well as the noticeable displacement of radial head fracture. If the anteroposterior wrist radiograph is normal, ultrasound and MRI can be used to diagnose interosseous membrane rupture. Herniation of the muscles into the interosseous space when passing the probe over the forearm in supination is an important sign of interosseous membrane injury". [42] MRI works well for identifying damage to the capitellar cartilage.[10]

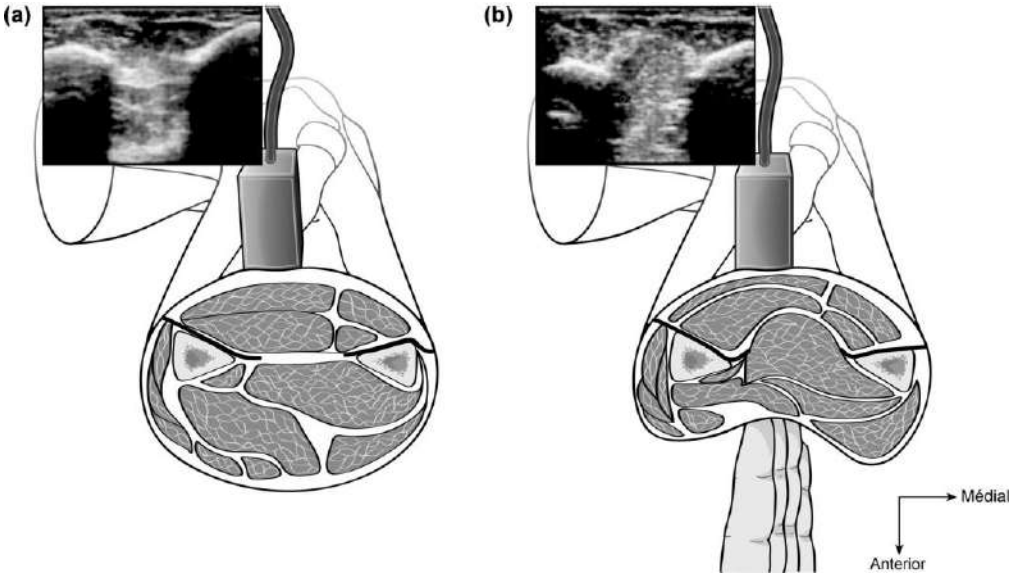


Figure 3: Muscular hernia sign" indicating a tear in the inter-osseous membrane.[42]

Treatment

Early initiation of "protected range of motion" is included in the conservative treatment approach for nondisplaced fractures. Historically, "radial head excision", ORIF, and RHA have been the surgical treatments used for treating displaced fractures and those linked to "complex elbow instability". When a fracture is associated with dislocation which affects the stability that damages the surrounding elbow ligament stabilizers, replacing the radial head has made it possible to repair non-reconstructible fractures and restore the radial head's stabilizing function.[43]

Open Reduction and Internal Fixation

The recommended surgical technique for Radial head fractures nowadays is ORIF. For the treatment of unstable, displaced RHF fractures, ORIF is seen to be superior to radial head excision with regards to strength, initial forearm and elbow stability, and preventing the development of arthrosis later. When the proximal radioulnar joint's smooth congruency is disrupted by improper fixation, it can cause pain, restrict joint motion, and potentially contribute to issues like osteoarthritis in nearby joints.[44]

Mason initially recommended performing “resection of comminuted fractured radial head” for the treatment of comminuted, displaced fractures; however, throughout the past few decades, many additional surgical procedures have been documented. “Resection of the radial head” may provide excellent results in situations of “isolated comminuted radial head fractures” without accompanying elbow instability. Aim of replacing radial head with silicone implants was to stabilize the elbow again, but this procedure led to several difficulties and issues with the implants. Management by ORIF gained popularity as a result. When ORIF was used for “stable radial head fractures”, positive outcomes were noted.

However, in comparison with fractures with either “two or three simple fragments”, Ring et al[17] demonstrated that “ORIF for Mason type III fractures” with >3 articular fragments was associated with a greater likelihood to provide unsatisfactory outcomes. These severely “comminuted unstable radial head fractures” are challenging to repair and may result in nonunion or hardware failure. Thus, when “firm internal fixation of the comminuted radial head” is not obtained, Moro et al. advocated using “metallic radial head prosthesis” (RHP).

In Chen et al study,[45] replacement group participants had significant improvement in PROMs following follow-up of 2 years when ORIF was compared with arthroplasty for “comminuted unstable radial head fractures”. In addition, in comparison with arthroplasty, more complications (such as infection, HO, nonunion, malunion, and limitation in motion) were observed after ORIF. The authors concluded that in clinical use, replacement is effective than ORIF. Nevertheless, they pointed out that the study's short-term follow-up did not reveal any issues with prosthesis wear, loosening, or ageing.

Lindenhovius et al[46] conducted a study to assess the outcomes of ORIF for “stable displaced partial articular fractures of radial head”. At the mean follow-up period of 22 years, it was found that despite favourable outcomes, 44% of participants experienced complications.

Ruan et al[18] in a study on “22 patients with Mason type III fractures”, compared ORIF with “radial head replacement”. Eight patients underwent ORIF, while fourteen received treatment with “bipolar metal head” prosthesis. Remarkably, only 12.5% of ORIF patients had “good to excellent” outcomes compared to 92.9% of prosthesis replacement patients.

A long-term study of 20 patients was conducted by Harrington et al.[15] At mean follow-up of 12.1 years, it was observed that 12 patients had excellent outcomes, 4 had good outcomes, 2 had fair results, and 2 had poor outcomes. Their findings imply that this construct has long-term efficacy.

Pike et al[24] (2014) conducted a study conducted study on 35 patients who “underwent ORIF for radial head fractures”. Out of these patients, 52 patients were in simple group (“underwent ORIF of radial head for isolated radial head fractures”) and 29 included in complex group (underwent “ORIF for radial head fracture with associated fracture or dislocation”). Patient-rated Elbow Evaluation was used for assessing pain and disability. The major complications in simple group were present in 13% patients and in 25% in complex group patients. Secondary capsular release in simple group was present in 3% patients and in 20% in complex group patients.

Walsh et al[47] (2023) conducted a study conducted study on 35 patients in whom ORIF was performed for radial head fractures. Out of these patients, 13 had radial head fractures with ≤2 intra-articular fragments and 22 had radial head fractures with ≥3 intra-articular fragments. In subgroups of 2, 3, and 4 fragment fractures, there were similar *Quick*DASH and Broberg and Morrey scores. Revision surgery was needed in 1 patient from each group.

Helstetter T et al[48] (2023) conducted study on 9 patients in whom ORIF was performed for radial head fractures. At follow-up of 49 years, mean “Broberg and Morrey score” was 95 points. Satisfactory results were

seen in 8 patients. All patients retained their radial heads in all 9 patients, demonstrating radiological fracture healing. Low-grade complications were seen in only 2 patients, not needing further surgery.

Treatment options for “mason type III and IV” remain controversial and K. Chaijenkij et al[49] performed “systematic review” to assess clinical outcomes after internal fixation, arthroplasty and resection for treatment of comminuted radial head fractures. He observed that ORIF could have an approximately 2.75 times higher risk of complications when compared to RHA in the treatment of comminuted “radial head fracture”.

Radial head arthroplasty

Non-reconstructible “radial head fractures” where the radial head's stabilizing function is impaired are considered as most frequent indications for RHA. This can be the case for “acute comminuted radial head fractures” that cannot be improved with ORIF. Malunion or nonunion, and chronic cases with instability after radial head resection, are additional causes for replacement.[50] In 1941, the first report on RHA was released.[51]

RHA has good to excellent “short- to mid-term” functional outcomes with advanced implant design and technical improvement. Nonetheless, there is a broad range in the literature's complication rates, with reoperation rates falling between 0% and 45%.[52] Painful loosening, osteolysis, capitellar erosion, and progressive ulno-humeral arthrosis are late complications of RHA in terrible triad injuries.[50,52,53]

Surgical approach

A “laterally based incision” made directly above radial head or “posteriorly based utilitarian incision” can be used for approaching the radial head. In patients with complex elbow instability, accessibility to “medial and lateral sides of the elbow” can be obtained through posteriorly based incision. The elbow incision is made in the middle, with a small curve encircling the olecranon process' tip. For

most cases of “isolated radial head replacements”, surgeons typically utilize a laterally based incision for direct access to the radial head. This approach involves making an incision directed towards “the supinator crest of the ulna”, starting just “proximal to the lateral epicondyle”. During surgery, the surgeon may choose to split the “extensor digitorum communis” or use “the Kocher or Kaplan intervals” for access. The “classic Kocher interval utilizes a small fat stripe between the anconeus and the extensor carpi ulnaris, but it poses a risk to the LUCL”. In contrast, the “Kaplan method utilizes the space between the extensor carpi radialis longus and brevis and the extensor digitorum communis”, potentially shielding the “LUCL from iatrogenic injury with distal extension”, though it increases the risk to PIN.[43]

Surgical technique

It is preferred to use a “laterally based incision” when doing “planned isolated” RHA. This strategy is favoured since it enables LUCL evaluation as well as management, which isn't possible with a Kaplan method. By locating “fat stripe beneath elbow fascia”, one can employ the Kocher interval. The incision of fascia is done “along the fat stripe proximally to the lateral epicondyle”. Joint capsule is carefully preserved proximally while the “anconeus is reflected posteriorly”. As “posterior flap, the lateral distal triceps” ought to remain continuous with the anconeus.[43]

The “distal extensor carpi radialis longus and common extensors are anteriorly reflected off the humerus”. When supinator is visible, it “is reflected off the radius”. The “capsule is incised from the lateral epicondyle to the supinator crest”. In cases of “complex elbow instability, LUCL is often disrupted”. The “RHA can be performed with the LUCL left intact, which is the preference of senior authors when possible. If greater exposure is necessary, the LUCL can be released from the epicondyle and marked for later repair. A micro sagittal saw is used to cut the radial neck at its base, and Hohmann retractor is placed over the radius to gently move it laterally away from the capitellum”.[43]

For most RHA cases, implants with smooth stems are preferred. Implant is tested after radial canal is opened up to anatomic fit. Undersize of the implant is preferred when measuring the head since overstuffing can induce erosion and be damaging to the elbow's stability. It can also exacerbate late capitellar pain. The ulna's lesser sigmoid notch can be visualized intraoperatively. To achieve the correct height, it is tried to line up the most proximal part of the lesser sigmoid notch with the proximal surface of the implant.[43]

For patients who are less experienced with RHA, intraoperative fluoroscopy can be helpful. However, it's crucial to understand that because the metal implant replaces bone and cartilage, it will seem larger compared to native radial head on radiographs. If necessary, a docking procedure is utilized for repairing the LUCL following the final prosthesis' implantation. To provide the lateral elbow more stability, the extensor musculature is also carefully repaired. Reconstruction of LUCL using “an autograft or allograft tendon” may be necessary in “chronic cases” with attenuated LUCL.[43]

Restoring the height of the radial head relative to the ulna is critical during RHA. Determining the correct implant size can be guided by assessing the range of motion post-implantation of the radial head. Evaluating the radio capitellar gap in both flexion and extension is also crucial. Six patients were described by Birkedal et al,[54] as having less flexion following RHA, necessitating the removal of the prosthesis to relieve pain. The radio capitellar gap was found to be “significantly smaller in flexion than in extension based on the results of the cadaver component”. “Subtle oversizing of the radial head implant can result in abutment on the radial fossa of the distal humerus, resulting in postoperative reductions in flexion” and pain.

An essential technical component of RHA is restoration of the “lateral ligamentous complex”.[43] Beingessner et al [55] conducted an investigation on cadaver employing “RHA with and without restoration of the lateral ligamentous complex as well as extensor muscles”; it was

found that “RHA alone did not entirely restore elbow stability until the LUCL was competent”. This finding underscores the need of “repairing or reconstructing the LUCL in the situation of a complex fracture-dislocation in which an RHA” will be employed.

Complications

After radial head surgery, reports of “postoperative elbow stiffness, pain, ulnar nerve palsy, PIN palsy, and heterotopic ossification” have been documented.[56] These side effects are not unique to this surgery; instead, they are most likely linked to the elbow's damage. Especially with “overaggressive retraction at radial neck”, PIN palsy might occur. Present “press-fit and loose-fitting stems” show radiolucencies surrounding the implant's stem. There is conflicting information in the literature regarding whether lucencies surrounding the stem signify loosening that causes forearm pain.[57,58] One complication observed with longer follow-up after RHA is “capitellar erosion”. This can result from increased wear due to the higher “modulus of elasticity of contemporary” radial head implants compared to the “native capitellar cartilage” and may be unavoidable. Overstuffing the radial head is believed to accelerate this process. Dislocation is a specific concern with bipolar prostheses, requiring vigilant monitoring due to its higher occurrence rate.[43]

Complications after RHA are due to contracture after prolonged immobilization or secondary to continuous pain, swelling, and inflammation. This may be due to an undetected osteochondral lesion of capitellum. Chronic pain may occur due to trauma to the triangular fibrocartilage, distal radioulnar joint, or interosseous membrane. Sometimes, in cases of free osteochondral fragments or joint incongruence, post-traumatic radial condyle osteoarthritis develops. Complex regional pain syndrome is linked to “radial head fractures” and occasionally arise following conservative or surgical management. Sometimes a hidden elbow fracture-dislocation happens, which can result in a late dislocation because the injured ligaments are not

treated. The following are some of the other side effects of RHA: failed components, radio-capitellar arthritis, and very big prosthesis.[20]

One of the most prevalent reasons for revision of RHA is elbow stiffness. About 5-15% of patients with elbow fractures may develop stiffness following surgery.[59] In cases of stiffness or instability, it is advisable to assess for “ulnar impaction syndrome (impingement between the ulnar head and the lunate) and DRUJ (Distal Radioulnar Joint) instability”. This evaluation includes obtaining bilateral radiographs of the wrists. Elbow stiffness can occur with or without OA or implant failure. These conditions can be evaluated using plain radiographs and CT scans.[50]

After elbow injuries, arthroscopy, open reduction internal fixation of fractures, and radial head replacement, heterotopic ossification (HO) is frequently observed. Following elbow injury, rates of HO can reach 50%.[60] Genetic predisposition, soft tissue injury, neurologic factors, and systemic diseases are risk factors for HO. Following RHA, the development of HO is linked to a substantially decreased “range of motion” following surgery and an elevated risk of reoperation. Even with early treatment, HO can become a late complication that impairs quality of life and causes pain and limited mobility. After surgery or an elbow injury, prophylactic treatment options like NSAIDs and/or radiation therapy are frequently utilized for preventing HO.[61]

Previous empirical studies on the functional outcomes after RHA in Radial head injuries

Kaur N et al[62] (2014) conducted study in Canada on 391 patients who underwent RHA, with an aim to find outcomes after surgery. The patients' average age was 48.4 years, with male-to-female ratio being 1.05: 1. The average follow-up duration was 47.2 months. The involvement of dominant arm was in 54% patients. The common mode of injury was fall on outstretched hand (68.4%) and fall from height (>6 feet) (14%) and motor vehicle accident (9.2%). "Mayo Elbow Performance Index (MEPI)" was used for assessing functional outcomes. After RHA, the mean MEPI was 85.8, indicating excellent outcomes. The mean "Broberg and Morrey functional rating score" was 85.6, indicating excellent outcomes. The incidence rate of "implant removal" and revision was 3.06% and 2.22%, respectively.

Moghaddam et al[63] (2016) conducted a study in Germany on 85 patients with "comminuted radial head fractures", who underwent RHA, with an EVOLVE® prosthesis. Out of these, 75 patients completed follow-up. The mean duration of follow-up was 41.5 months. The number of "Mason II, III and IV fractures" were 2 (2.7%), 21 (28%), and 52 (69.3%) respectively. The average values of Morrey, MEPI, and DASH score were 85.7, 83.3, and 26.1 respectively. In comparison to non-injured side, affected joint had significantly lesser mean flexion/extension (125.7°/16.5°/0° vs. 138.5°/0°/1.2°, ($p<0.05$) and mean pronation/supination (70.5°/0°/67.1° vs. 83.6°/0°/84.3°). In comparison with the non-injured arm, handgrip strength of the injured arm was 78.8%. Complications included: periprosthetic radiolucency (n=58) which was not clinically significant and relevant as per assessed scores; moderate/severe periarticular ossification (n=26) and scored significantly worse as per MEPI and Morrey scores. Revisional surgery was needed in 4 patients because of prosthesis loosening and chronic pain. Complications were paralysis of the ulnar nerve occurred in 1 patient, neo bursa (n=1), and extensive swelling and blistering (n=1).

There was an effect of time interval between injury and treatment on outcomes as better results were seen in patients treated within the first 5 days after accident (n=35) in comparison to those who were treated after 5 days (n=40). The results led to the conclusion that a modular radial head prosthesis can effectively treat “comminuted radial head fractures” with elbow instability by restoring stability during acute treatment. The modular RHA technique produced encouraging short- to midterm outcomes.

Kadam et al[64] (2017) conducted a study in India on 18 patients (12 males) with radial head fracture who underwent RHA, with an aim to find outcomes after surgery. The mode of injury was fall on an outstretched hand (n=8), road traffic accident (n=6), and history of assault (n=4). MEPS was used for evaluating functional outcomes, demonstrating excellent outcomes in 13(72%), good in 3(17%), fair outcomes 2(11%) patients, and poor outcomes in none of the patients. Elbow instability, infection, and implant loosening were not present in any patient. The results led to the conclusion that for treatment of “comminuted radial head” fractures, RHA has a high success rate.

Kulkarni V et al[65] (2020) conducted a study in India on 30 patients with “radial head fracture” who underwent RHA, with an aim to find outcomes after surgery. The patients’ mean age was 40.3 years, with 18 being males. The side affected was right in 16 patients and left in 14 patients. The common modes of injuries were “road traffic accident” in 18(60%) patients and fall in 12(40%) cases. The most common “indications for surgery” included type III and IV fractures in 22 and 8 cases, respectively. Evaluation was done postoperatively and at follow-ups at first, third, and sixth month by MEPI Score, with mean score being 80.34, 86.64, and 91.84, respectively. MEPS demonstrated excellent outcomes in 20(66.66%) patients, good in 8(26.66%), fair outcomes 1(3.33%) patient, and poor outcomes in 1(3.33%) patient. CRPS and elbow joint stiffness were present in one patient each.

Chen AC et al[52] (2021) conducted a study in Taiwan on “patients with radial head fracture” who underwent RHA, with an aim to find and compare outcomes at 2 and 10 years after surgery. Periprosthetic osteolysis was used for measuring radiolucency score. Assessment was performed by “MEPS, self-reported scales of shortened Disabilities of the Arm, Shoulder, and Hand (QuickDASH)” and VAS. Compared to follow up at 2 years, outcomes at 10 years included similar MEPS (82.5 ± 15 vs. 84.2 ± 14.4 p=0.348), QuickDASH score (14.1 ± 14.3 vs. 12.2 ± 12.6 p=0.306), VAS score (1.6 ± 1.2 vs. 1.5 ± 0.8 p=0.337) (indicating decline in functional status), and significantly higher Radiolucency score (7.4 ± 4.2 vs. 2.6 ± 2.3, p=0.000).

Schnetzke M et al[66] (2021) conducted a study in Germany on 78 patients who underwent monopolar RHA, at least 6 years previously. The patients’ mean age was 59.2 years. At median follow-up of 9.5 years, the median MEPS, QuickDASH, VAS, postoperative satisfaction, and arc of extension/flexion were 80.0, 22.0, 1, 2, and 110°, respectively. At median follow-up duration of 7 years, radiography assessment was performed in follow-up in 48 patients. Complications were seen in 29 (37.2%) patients, RHA exchange/removal occurred in 20(25.6%) patients. At 18 years, survival rate of 75.1% was seen on Kaplan-Meier analysis. The greatest annual failure rate was seen in 1st year in which RHA of 7(9%) patients were either exchanged or removed. Type of RHA showed no significant association with MEPS score (Mathys vs. Evolve: 82.5% vs. 80%, *P*=0.341) and QuickDASH score (Mathys vs. Evolve: 12.5 vs. 26.7, *P* =0.112). In comparison with delayed surgery, Early surgery (≤3 weeks) showed significantly better MEPS score (80 vs. 52.5; *P* =0.014) and QuickDASH score (18.6 vs. 46.2, *P* =0.002). In comparison to patients with removed RHAs, those with retained RHAs showed significantly better MEPS (80 vs. 70, *P*=0.016) and QuickDASH (18.1 vs. 49.1, *P*=.007). The results concluded that the long-term results of RHA are satisfactory, but there was high rate of

complications and revisions. At 18 years, the implant survival rate was 75.1%, with the greatest annual failure rate occurring in the 1st year following surgery.

Lobo-Escolar L et al[67] (2021) conducted a study on 45 “patients with complex radial head fractures”, who underwent treatment with RHA and press-fit radial head prosthesis. The patients’ mean age was 45 years, with 32(71%) being males. In 29 (64.4%) patients, left side was injured. In 32 (71.1%) patients, Mason IV fracture was present. "Terrible triad" was present in 62.2% patients. Re-operation and prosthesis removal were done in 26.7% and 15.6% patients, respectively. The mean duration of follow-up was 140.8 months. At 24 months, prosthesis survival was 69.5%. The commonest reasons for re-operation were pain and instability. Complications were present in 12(26.7%) patients.

Davey MS et al[68] (2022) conducted a “systematic review and meta-analysis” including 10 studies Total 432 elbows were included. There were 51% males, and the patients’ mean age was 50 years. The mean duration of follow-up was 117 months. The criterion for inclusion of studies in this systematic review was the studies that assessed outcomes of RHA with at least mean 8 years of follow-up. The mean values of MEPS and Quick DASH scores were 83 and 17 respectively. There was minimal or no pain in 86% of the patients. The overall rate of dislocation was 2%, subluxation (4%), ulnar neuritis (3%), and infection (3%). Radiologic loosening was present in 9% patents, degenerative change in 27%, radiolucency in 46%, and heterotopic ossification in 38% patients. Surgical revision was needed in 20% patients. RHA implant revision was required in 3% patients, metal/implants removal in 15%, and arthrolysis in 5% patients. It was concluded that even with significant levels of radiological degenerative changes over the same period, RHA produces good clinical outcomes and less rates of complication and revision at long-term follow-up.

Kandel M et al[70] (2022) conducted a study in Nepal on 96 patients with “radial head fracture”, with an aim to assess the outcome of RHA. The patients’ mean age was 38 years, with 16 (72.73%) being males. The commonest mode of injury was fall on an outstretched hand [12(54.55%) patients], road traffic accident [6(27.27%)], and assault [4(18.18%)]. Following surgery, the Mayo elbow score was used to calculate the functional result at three-, six-, and twelve-month intervals. 22 (22.92%) of the 96 patients who had radial head fractures had RHA. Following a year, the mean Mayo elbow score was 96.33±7.74. Excellent elbow performance scores were seen in 20(90.91%) patients, good outcomes in 1(4.54%) and fair outcomes in 1 (4.54%) patient; poor outcomes were not present in any patient. After surgery, the mean supination, and flexion arc were 85.92°, 83.73°, and 115.91°, respectively. None of the patients had elbow instability, infection, and implant loosening. Superficial wound infections were present in 3(13.64%) patients the healing of which occurred following wound debridement and dressing. At 1st-month of follow-up, elbow joint stiffness was present in 1 (4.54%) patient that improved later.

Foroohar A et al[69] (2022) conducted a study in the USA on 970 participants, who had radial head fractures and underwent primary unilateral RHA; the study aimed at finding functional outcomes. The patients’ mean age was 53.9 years, with 60.6% being females. The most common indication for surgery was fracture (98.4%). In 54.3% patients, concomitant procedures were done. Press fit, over loose fit, and monopolar implants were used in 63.2%, 36.8% and >90%. After RHA, the 3-year cumulative revision probability was 6.5% and reoperation probability was 8.2%. Most of the revisions and reoperations occurred within 1st year postoperatively. Within 90 days, emergency department visit was needed in 83 (8.5%) and readmission in 58 (6%) patients. One (0.1%) patient died within 90 days.

Raven TF et al [70] (2023) conducted a study in Germany on 30 participants, who had comminuted radial head fractures and underwent arthroplasty with an EVOLVE® prosthesis, aiming to assess the functional outcomes. Among these patients, 20 were followed-up at period of >10 years. The evaluation of outcomes was done as per Broberg-Morrey elbow evaluation score, which demonstrated that 10(50%) patients had very good outcomes, 4(20%) had good, 6(30%) had satisfactory; poor outcomes were not seen in any patient, at mean follow-up duration of 10.2 years. When outcomes were assessed for long term, increased Broberg-Morrey score [from 79 to 89 points] was noted. The mean DASH score was 16.2 points. Patients' initial 20° extension deficit decreased to 5° at the most recent follow-up. Long-term outcomes suggested that metallic modular radial head implant used in arthroplasty improved elbow function. The “EVOLVE® radial head prosthesis” is an excellent treatment for comminuted radial head fractures with elbow instability. After 10.2 years, the long-term findings show lesser major complication rate and satisfactory functional outcome.

Ajrawat et al[71] (2023) carried out a prospective observational study in India on 25 patients, in whom RHA was performed, with an EVOLVE® prosthesis, aiming to assess functional outcomes. The patients’ mean age was 41.23 years, with 56% being males. The common modes of injuries were road traffic accident [14(56%)] and fall [11(44%)]. Based on Mason fracture type, Type III was present in 19(76%) and Type IV in 6(24%) patients. The MEPS was used for measuring functional outcomes, which showed that there was significant improvement in MEPS at 3rd-month follow-up in comparison to 1-month (87.24 ± 12.42 vs. 81.54 ± 11.18, P<0.001). There was further increase in MEPS at the 6th month follow-up (92.14±7.36) (P<0.001). The last follow-up was done at 6 months, which demonstrated excellent outcomes in 80% patients, good outcomes in

12%, fair outcomes in 4%, and poor outcomes in 4% patients. Complex regional pain syndrome and joint stiffness were present in one patient.

MATERIALS AND METHODS

Study duration: This study was conducted over a period of 32 months from 1st January 2021 to 31st August 2023. (14 months retrospectively, from 1st January 2021 to 28th February 2022 and 18 months prospectively, from 1st March 2022 to 31st August 2023)

Study design: Retrospective and prospective hospital-based study

Study site: The study was carried out at Dayanand Medical College and Hospital, which is tertiary care, referral hospital of North India.

Study population: All patients admitted to Dayanand Medical College and Hospital, with Mason type III and Mason type IV radial head fractures scheduled to undergo radial head replacement between 1st January 2021 and 31st August 2023 were selected for the study. 6 retrospective cases and 20 prospective cases were identified according to inclusion and exclusion criteria, and a total sample size of 26 cases was obtained.

Sample size

The sample size for the study was calculated by formula taking the results of a previous study by Kulkarni V et al[65] as reference. The study observed that MEPS demonstrated poor outcomes in 1(3.33%) patient. With 7.5% margin of error and 5% level of significance, after formula application, the minimum samples needed were 22 patients.

Formula used:-

$$n \geq (p(1-p))/(ME/z_{\alpha})^2$$

Where Z_{α} is value of Z at two sided alpha error of 5%,

ME is margin of error

p is proportion of patients with poor outcome

Calculations:-

$n>=((.033*(1-.033))/(.075/1.96)^2=21.79=22$(approx.)

Inclusion criteria

- All patients presenting with radial head fractures planned for RHA
- All patients undergoing RHA using metallic head implant prosthesis (cobalt chromium and titanium head implants)
- Patients undergoing radius head arthroplasty by any surgical approach (posterior, medial, lateral, anterior or global approaches)

Exclusion criteria

- Any patient not giving consent
- Any patient below the age of 18 years or with incomplete fusion of epiphysis
- Any patient with radial head fracture planned for ORIF or radial head excision
- Any patient with pre-existing prosthesis or metal work in situ

Source of Data

All patients were evaluated based on MEPS (Mayo Elbow Performance Scores), elbow flexion, elbow extension deficit, supination and pronation, in the immediate post-operative period, at 3 months and then at 6 months respectively to analyse the functional outcomes in patients.

Standard predesigned structured proforma was filled in direct interview with patient.

Methodology

The study was conducted in the Department of Orthopaedics, Dayanand Medical College and Hospital, Ludhiana over a period of 32 months from 1st January 2021 to 31st August 2023, after due approval from the institutional ethics committee and review board and taking

written informed consent from the patients. The patient information sheet is attached as Appendix I.

6 retrospective cases, between 1st January 2021 and 28th February 2022 and 20 prospective cases, between 1st March 2022 and 31st August 2023, above the age of 18, with Mason type III or Mason type IV radial head fractures were enrolled in the study, after taking written informed consent. The demographic details included age, gender, religion and occupation of the patient. Details of mode of injury, type of fracture, and associated injuries were noted. Detailed preoperative history was taken. Physical examination was done on the previous day of surgery. The patient was provided with a detailed explanation of the procedure through a patient information sheet. The patient's details were recorded as per study proforma attached as Appendix I.

Surgical approach was either Kocher's or posterior, based on treatment of associated injuries around the elbow joint. Cases with associated fractures of the olecranon with radial head fracture (Mason type III or type IV) were treated using the posterior approach. Cases with isolated radial head fractures or radial head fractures (Mason type III or type IV) associated with fracture of coronoid process or collateral ligament injuries of the elbow were treated using Kocher's approach.

Duration of surgery and blood loss during surgery were noted. Assessment of elbow flexion, elbow extension deficit, supination, pronation at immediate post-operative, post-operative 3 and 6 months was done. Assessment of pain by VAS score, motion arc, elbow joint stability, activities of daily living and Mayo elbow performance score (MEPS) at immediate post-operative, post-operative 3 and 6 months was done for all prospective cases. For retrospective cases, data was obtained from retrospective analysis of inpatient file data and monthly follow up outpatient department (OPD) cards. Data on assessment of pain, activities of daily living and Mayo elbow performance score was obtained using direct interview with the patient.

Surgical technique: (Approaches)

Choosing surgical approach

All Mason type III and Mason type IV radial head fractures were treated using metallic radial head implant prosthesis (cobalt chromium and titanium head implants) and surgical approach was chosen based on treatment of associated injuries around the elbow joint.

As specified in the thesis plan, decision to choose the surgical approach was undertaken for radial head replacement as well as to treat associated injuries of the elbow joint. In cases of isolated fractures of radial head or those associated with coronoid fracture or collateral ligament injury, Kocher's approach was used. Whereas in cases with associated fractures of the olecranon with radial head fracture, posterior approach was used, keeping in mind the benefits of single approach and minimising further soft tissue damage to the patient.

Kocher's approach

Patient positioning and preparation

The patient was kept supine with affected side's shoulder kept in 90 degrees of abduction, elbow kept in 90 degrees of flexion and fully pronated forearm positioned on a radiolucent side support table. Tourniquet was applied, painting and draping, using sterile technique was performed.

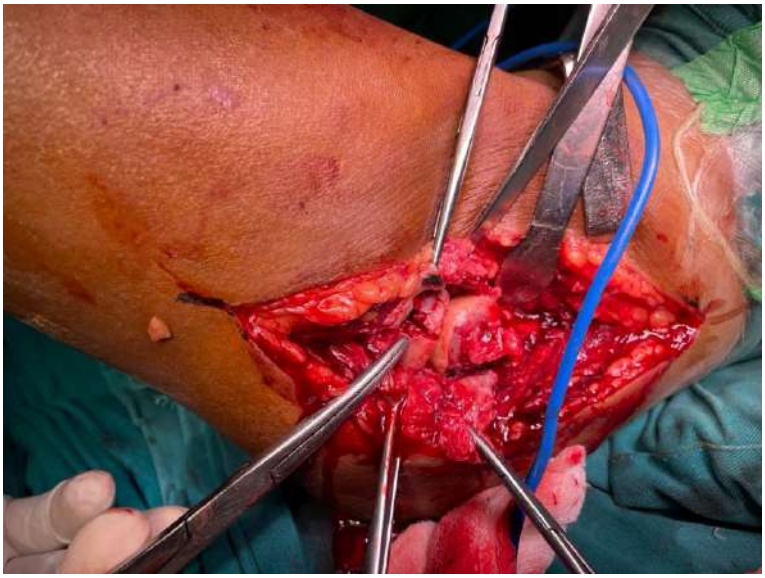
Operative technique

Limb was exsanguinated and tourniquet inflated. With the elbow in 90 degrees of flexion and forearm pronated, lateral epicondyle of humerus and radial head were marked and a curved skin incision of about 6-8 cm was given. Subcutaneous tissue was incised in line with the incision and fascia over the muscles was exposed. Kocher interval was identified between the extensor carpi ulnaris and anconeus muscles. Proximal fibres of the supinator muscle were split staying on the posterior cortex of the radius away from the posterior interosseous nerve. Annular ligament was divided in line with the muscle interval and

capsule was incised longitudinally to expose the radial head. Resection of the radial head was performed using saw and head size was measured. Reaming of radial shaft was done, and implant of appropriate size was chosen and inserted. Concomitant repair of associated fracture coronoid, if present was done using appropriately sized screws and repair of associated injury of lateral collateral ligament, if present was done using non absorbable anchor sutures. Range of motion and implant position was confirmed under fluoroscopic guidance and the surgical wound was irrigated and closed in layers. A sterile surgical dressing and above elbow fibreglass slab was applied.

Preop X-Ray Of A 42y/F With Radial Head Fracture (Mason Type III)

Kocher Interval Identified Between The Extensor Carpi Ulnaris And Anconeus Muscles

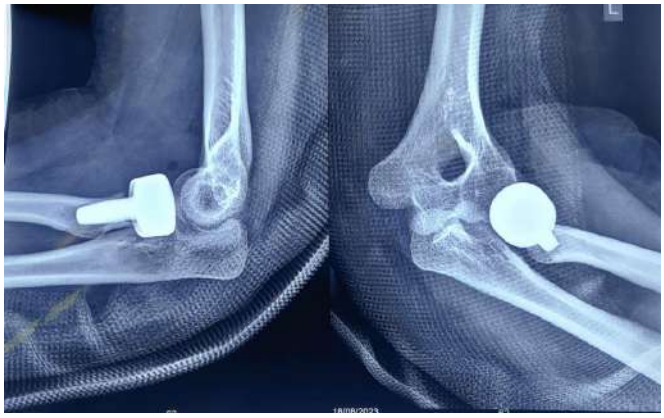


Exposing The Fractured Radial Head

Resected Radial Head With Visible Fracture Fragments

Inserted Radial Head Prosthesis

Fluoroscopic Confirmation Of Radial Head Prosthesis Position



Final Post Op X-Ray Of A 42y/F With Radial Head Fracture (Mason Type III)

Posterior approach

Patient positioning and preparation

The patient was kept in lateral decubitus position with affected side's shoulder kept in 90 degrees of abduction and forward flexion, elbow kept in 90 degrees of flexion positioned on a radiolucent side support table. Tourniquet was applied, painting and draping, using sterile technique was performed.

Operative technique

Limb was exsanguinated and tourniquet inflated. Olecranon was marked and skin incision was given 5cm proximal in the midline of the posterior distal humerus and was curved laterally around the tip of the olecranon and then curved medially over the posterior aspect of ulna. Ulnar nerve was identified, fully dissected, tagged and retracted medially. Deep posterior fascia was incised in the midline and olecranon osteotomy was performed using saw. The olecranon fragment was retracted proximally with the attached triceps muscle. Fascia covering anconeus and extensor carpi ulnaris was identified and incised longitudinally. Anconeus and extensor carpi ulnaris were elevated subperiosteally to reveal the supinator muscle which was also elevated, capsule was identified and incised to expose the radial head. Resection of the radial head was performed using saw and head size was measured. Reaming of radial shaft was done, and implant of appropriate size was chosen and inserted. Concomitant repair of associated injury of lateral or medial collateral ligament, if present was done using non absorbable anchor sutures. Repair of associated fracture of the olecranon and osteotomy site was done using appropriately sized plate and screws. Range of motion and implant position was confirmed under fluoroscopic guidance and the surgical wound was irrigated and closed in layers. A sterile surgical dressing and above elbow fibreglass slab was applied.

Other surgical approaches

In cases of associated injuries of ulnar/medial collateral ligament with a radial head fracture (Mason type III or IV), surgical replacement of radial head was carried out using Kocher's approach and concomitantly, medial approach to elbow was utilized to perform a repair of the ligament using non absorbable anchor sutures.

Medial approach- Operative technique

After marking the medial epicondyle, a curved incision 6-8cm long was given centered over the medial epicondyle along the medial aspect of the elbow. Ulnar nerve was identified and dissected after incising superficial fascia. Common flexor origin was exposed, and an interval was developed between brachialis and pronator teres muscles. Medial collateral ligament was identified and repaired using bioabsorbable anchor sutures.

Postoperative Protocol

Dose of postoperative antibiotics was given with adequate pain control medications. Wrist and finger mobilisation exercises were started in the immediate postoperative phase. Suture removal was routinely done on the 14th day. Passive elbow mobilisation exercises were advised after four to six weeks. Active elbow mobilisation exercises were advised after ten to twelve weeks. All patients were followed up monthly, upon which clinical, and radiographic evaluation was done to assess healing.

Post-operative Method of Assessment:

Assessment of elbow flexion, elbow extension deficit, supination, pronation at immediate post-operative, post-operative 3 and 6 months was done. Assessment of pain by VAS score, motion arc, elbow joint stability, activities of daily living and Mayo elbow performance score (MEPS) at immediate post-operative, post-operative 3 and 6 months was done.

Assessment of elbow flexion, extension deficit

With the patient standing/seated comfortably, arms adducted, shoulder in 90 degrees of forward flexion and fully supinated forearm.

One 360° scale (1°-increments) plastic universal goniometer with two 25-cm arms was placed, centered over the lateral epicondyle of elbow with the stationary arm aligned along the humerus, pointing towards the tip of the acromion and mobile arm aligned along the radius shaft, pointing towards the radial styloid.

The goniometer had 1°-increments and measurements for elbow flexion, extension deficit and motion arc were recorded with a precision of ± 0.5°.

Assessment of elbow supination, pronation

With the patient seated comfortably, arms adducted, shoulder in neutral position, 90 degrees of elbow flexion and pencil held in the distal palmar groove of the palms.

One 360° scale (1°-increments) plastic universal goniometer with two 25-cm arms was placed, centered over the head of the third metacarpal, with the stationary arm placed parallel to the humeral midline and mobile arm placed parallel to the pencil.

The goniometer had 1°-increments and measurements for elbow supination, pronation were recorded with a precision of ± 0.5°.

Visual analog scale (VAS)

The VAS, a pain rating scale, measures acute as well as chronic pain. It was first used by Hayes and Patterson in 1921.[72] Scores are derived from “self-reported symptom measures, where patients mark a single point along a 10-cm line representing a continuum between no pain at the left end (0 cm) and worst pain at the right end (10 cm). The distance from the start of the scale (left end) to the patient's mark is recorded in centimeters, indicating their level of pain. These values can

track pain changes over time for a patient or compare pain levels among patients with similar conditions".[73]

Mayo Elbow Performance Score (MEPS)

The "MEPS, also referred to as the Mayo Elbow Performance Index, is the most frequently utilized method for evaluating elbow impairments. Originally detailed by Morrey et al[74] this scoring system modifies the evaluation approach developed by Broberg and Morrey for assessing outcomes of elbow fractures and dislocations treatments. The MEPS evaluates four components: pain, range of motion, stability, and patient-rated daily function, with pain given the most significant weight. The range of total score is between 0 and 100, where a higher score signifies a better outcome".[75]

Outcome measures included elbow flexion, elbow extension deficit, supination, pronation, and Mayo Elbow Performance Score (MEPS). Complications were noted immediate post operatively and at follow-up of 3 and 6 months.

Statistical Analysis

The "presentation of the Categorical variables was done in the form of number and percentage (%). The quantitative data were presented as the means ± SD and as median with 25th and 75th percentiles (interquartile range). Shapiro-Wilk test was used for assessing data normality. The cases in which the data was not normal, we used nonparametric tests". The following statistical tests were applied for the results:

1. The "comparison of the variables which were quantitative and not normally distributed in nature were analysed using Friedman Test followed by multiple pairwise comparisons using Nemenyi's procedure and variables which were quantitative and normally distributed in nature were analysed using repeated measure ANOVA followed by multiple pairwise comparisons using Bonferroni correction for paired comparison.

2. The comparison of the variables which were quantitative and not normally distributed in nature were analysed using Mann-Whitney Test and variables which were quantitative and normally distributed in nature were analysed using independent t test.
3. The comparison of the variables which were qualitative in nature were analysed using Bhapkar test for paired proportions. The comparison of the variables which were qualitative in nature were analysed using Fisher's exact test as at least one cell had an expected value of less than 5.

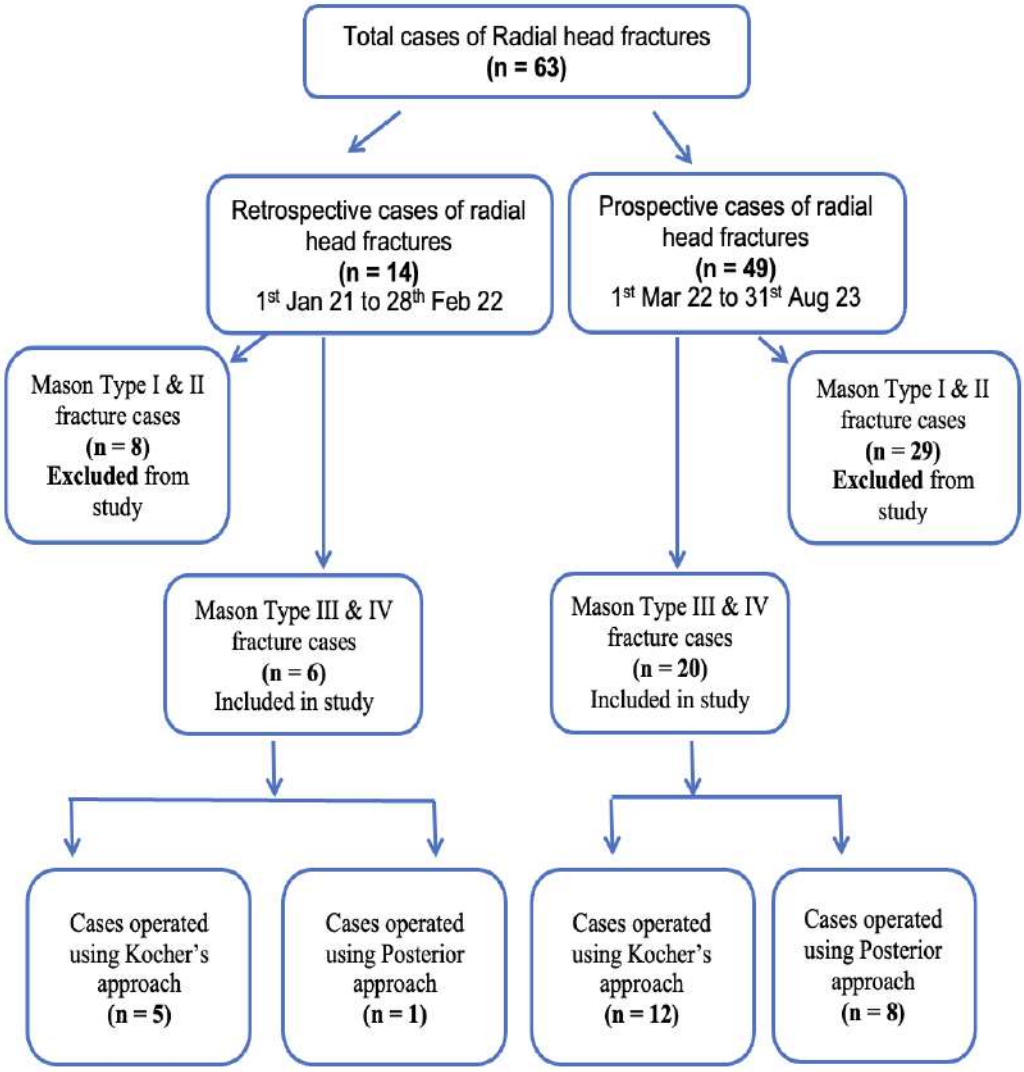
The "data entry was done in the Microsoft EXCEL spreadsheet, and the final analysis was done with the use of Statistical Package for Social Sciences (SPSS) software, IBM manufacturer, Chicago, USA, ver 25.0".

For "statistical significance, p value of less than 0.05 was considered statistically significant".

Ethical considerations

Ethical approval from the "institutional ethics committee was obtained before initiating the study. Written informed consent was obtained from all study participants. Throughout the study, strict measures were taken to ensure privacy as well as confidentiality".

OBSERVATIONS AND RESULTS


Total cases of Radial head fractures
(n = 63)
Retrospective cases of radial head fractures
(n = 14)
1st Jan 21 to 28th Feb 22
Prospective cases of radial head fractures
(n = 49)
1st Mar 22 to 31st Aug 23
Mason Type I & II fracture cases
(n = 8)
Excluded from study
Mason Type I & II fracture cases
(n = 29)
Excluded from study
Mason Type III & IV fracture cases
(n = 6)
Included in study
Mason Type III & IV fracture cases
(n = 20)
Included in study
Cases operated using Kocher's approach
(n = 5)
Cases operated using Posterior approach
(n = 1)
Cases operated using Kocher's approach
(n = 12)
Cases operated using Posterior approach
(n = 8)

This prospective and retrospective study was conducted at Dayanand Medical College and Hospital from 1st January 2021 to 31st August 2023. During this time, a total of 63 patients presented with radial head fractures. 26 patients presenting with radial head fractures (Mason type III or IV) planned for RHA were included in the study. Functional outcomes in the immediate post-operative period as well as at 3 months and 6 months were evaluated and results are as follows.

Table 2: - Age distribution.

Age	Frequency	Percentage
21 to 30 years	5	19.23%
31 to 40 years	3	11.54%
41 to 50 years	5	19.23%
51 to 60 years	6	23.08%
>60 years	7	26.92%
Mean ± SD	49.08 ± 16	
Median(25th-75th percentile)	51(32.5-61.5)	
Range	25-82	

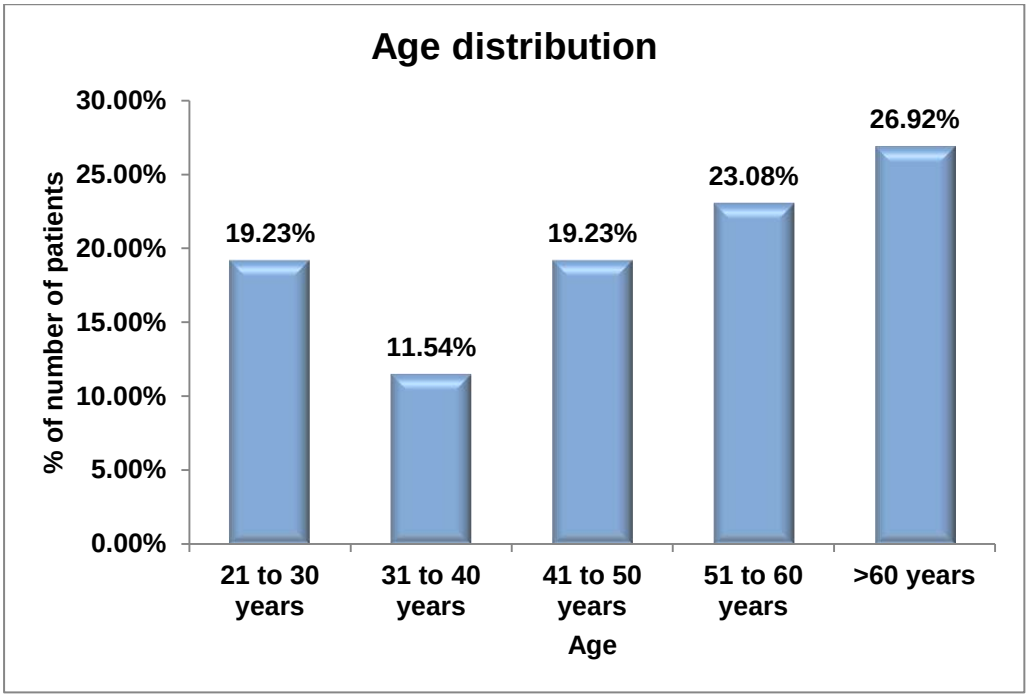


Figure 4: - Age distribution.

The age distribution of the cases was as follows: 7 cases (26.92%) were over 60 years, 6 cases (23.08%) were 51 to 60 years, 5 cases (19.23%) were 21 to 30 years, 5 cases (19.23%) were 41 to 50 years, and 3 cases (11.54%) were 31 to 40 years. The mean age of the study subjects was 49.08 ± 16 years, with a median (25th-75th percentile) of 51 years (32.5-61.5). (Table 2, figure 4).

Table 3:- Gender distribution.

Gender	Frequency	Percentage
Female	14	53.85%
Male	12	46.15%
Total	26	100.00%

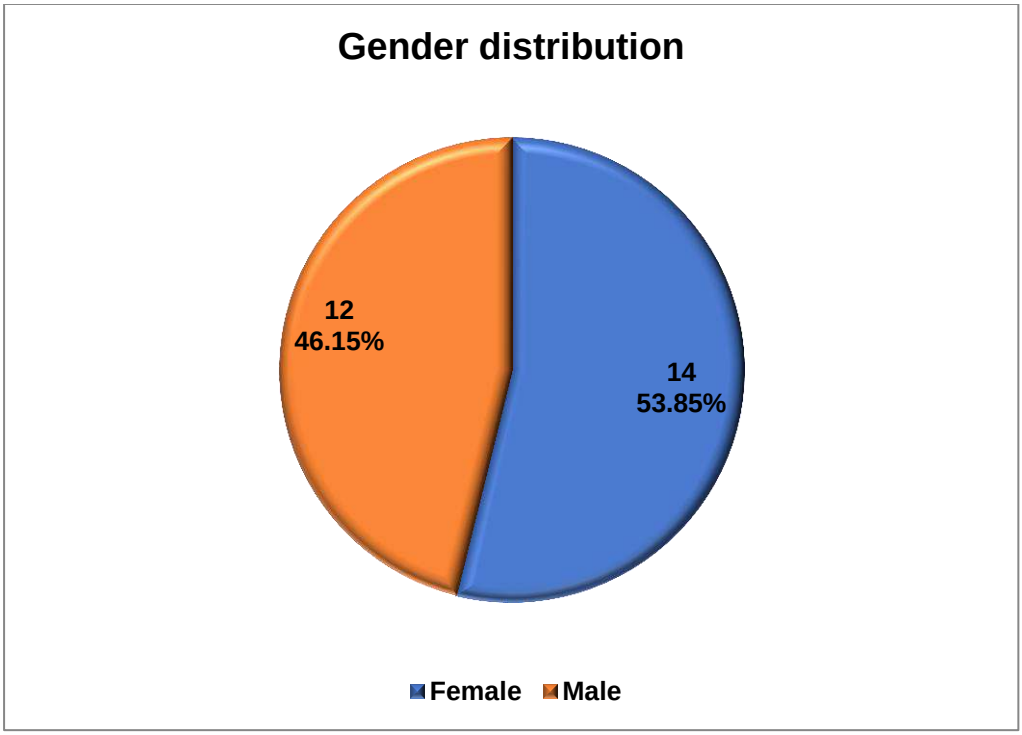


Figure 5:- Gender distribution.

In the study, 14 patients (53.85%) were female, and 12 patients (46.15%) were male. (Table 3, figure 5).

Table 4:- Occupation distribution.

Occupation	Frequency	Percentage
Businessman	4	15.38%
Engineer	2	7.69%
Homemaker	13	50.00%
Mechanic	1	3.85%
Property dealer	1	3.85%
Retired Government employee	1	3.85%
Retired laborer	1	3.85%
Shop owner	1	3.85%
Student	2	7.69%
Total	26	100.00%

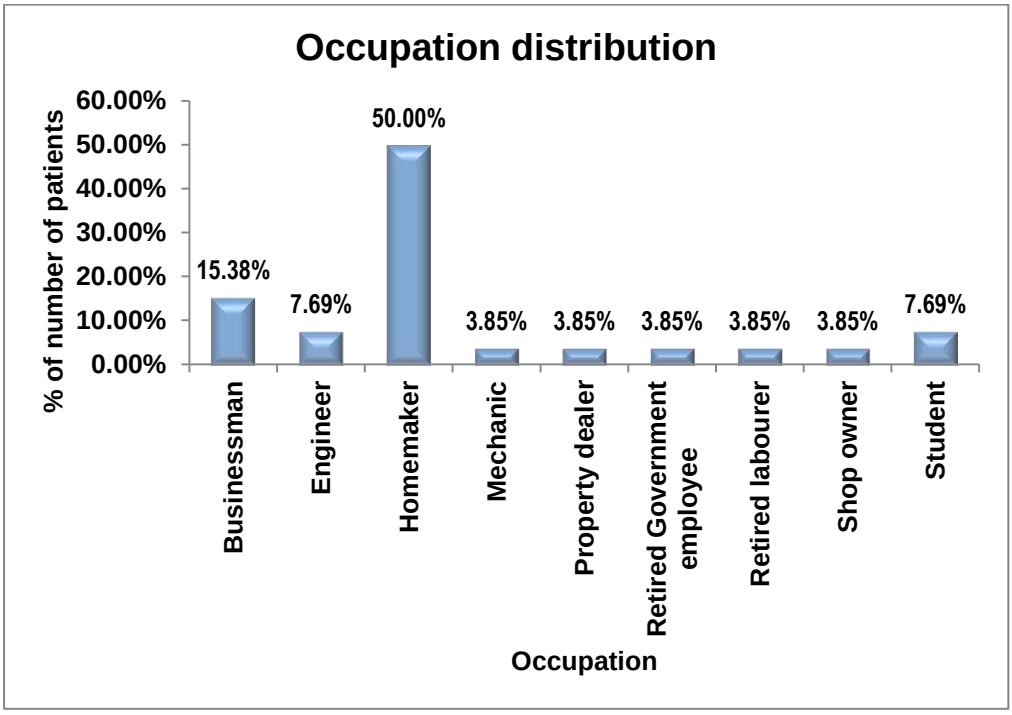


Figure 6:- Occupation distribution.

The occupation distribution of the cases was as follows: 13 cases (50.00%) were homemakers, 4 cases (15.38%) were businessmen, 2 cases (7.69%) were engineers, 2 cases (7.69%) were students, and 1 case (3.85%) each was a mechanic, property dealer, retired government employee, retired laborer, and shop owner. (Table 4, figure 6).

Table 5:- Mode of injury distribution.

Mode of injury	Frequency	Percentage
Assault	1	3.85%
Domestic fall	4	15.38%
RTA	21	80.77%
Total	26	100.00%

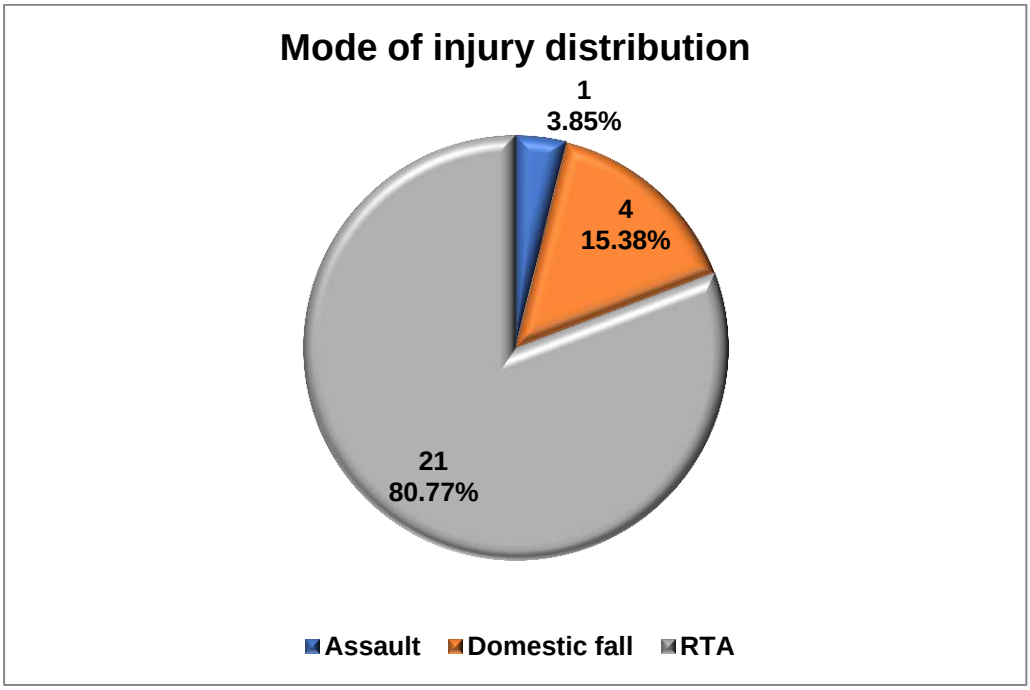


Figure 7:- Mode of injury distribution.

Modes of injury were distributed as follows: 21 cases (80.77%) were due to road traffic accidents (RTA), 4 cases (15.38%) were due to domestic falls, and 1 case (3.85%) was due to assault. (Table 5, figure 7).

Table 6:- Diagnosis distribution.

Diagnosis	Frequency	Percentage
Type III	13	50.00%
Type IV	13	50.00%
Total	26	100.00%

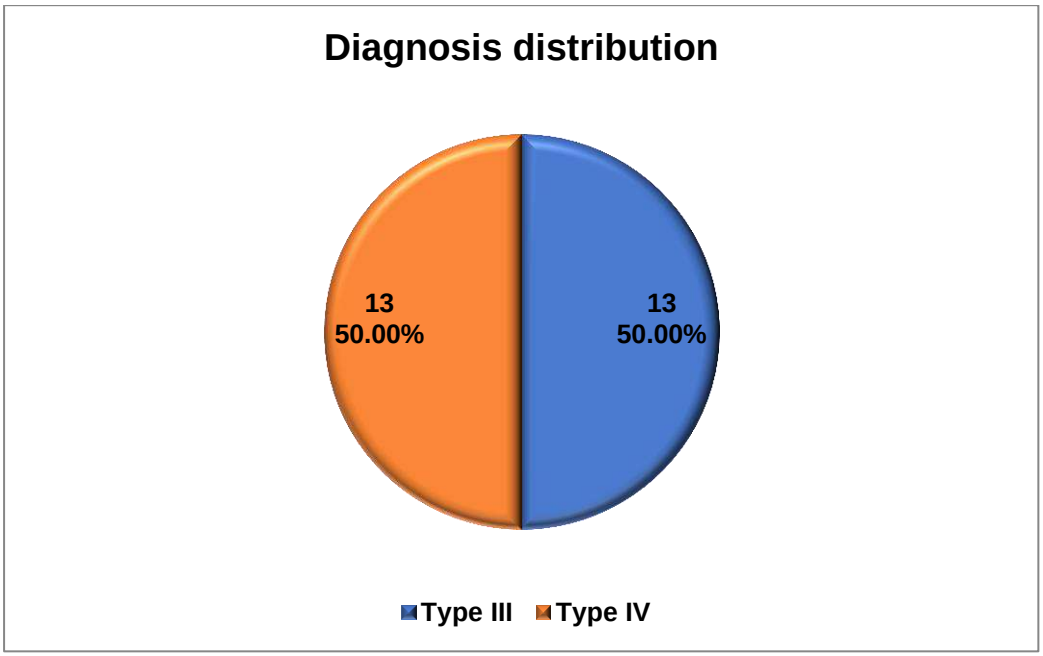


Figure 8:- Diagnosis distribution.

The diagnosis was type III in 13 cases (50.00%), type IV in 13 cases (50.00%). (Table 6, figure 8).

Table 7:- Associated injuries distribution.

Associated injuries	Frequency	Percentage
None	11	42.31%
LCL	8	30.77%
MCL	4	15.38%
Fracture Coronoid	2	7.69%
Fracture Olecranon	8	30.77%

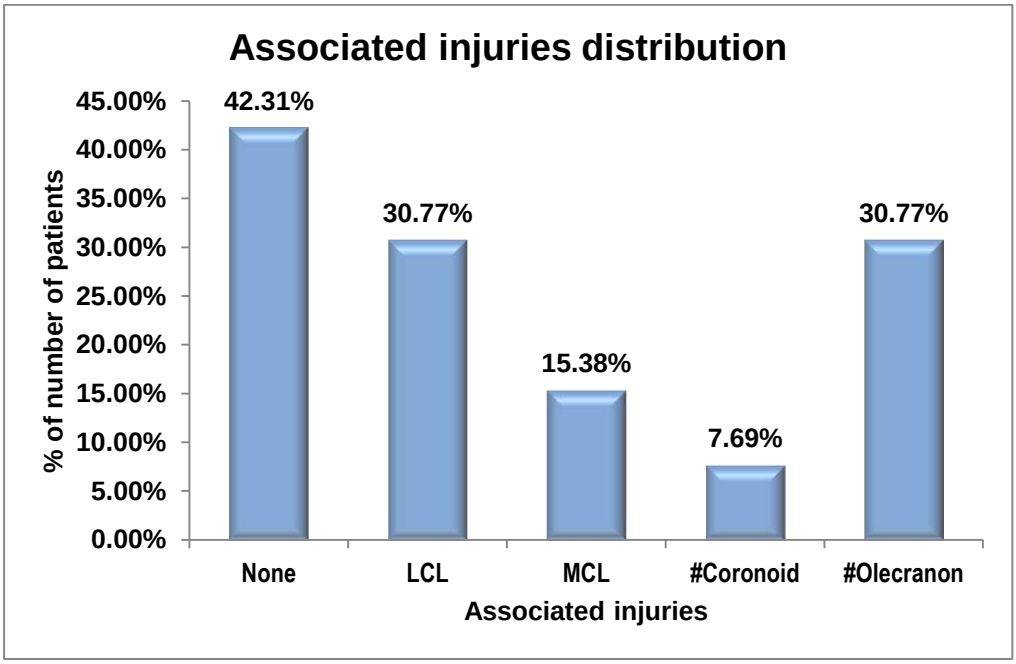


Figure 9:- Associated injuries distribution.

The associated injuries were distributed as follows: 11 cases (42.31%) had no associated injuries, 8 cases (30.77%) had LCL injuries, 8 cases (30.77%) had olecranon fractures, 4 cases (15.38%) had MCL injuries, and 2 cases (7.69%) had coronoid fractures. (Table 7, figure 9).

Table 8:- Surgery approach distribution.

Surgery approach	Frequency	Percentage
Kocher's	17	65.38%
Posterior	9	34.62%
Total	26	100.00%

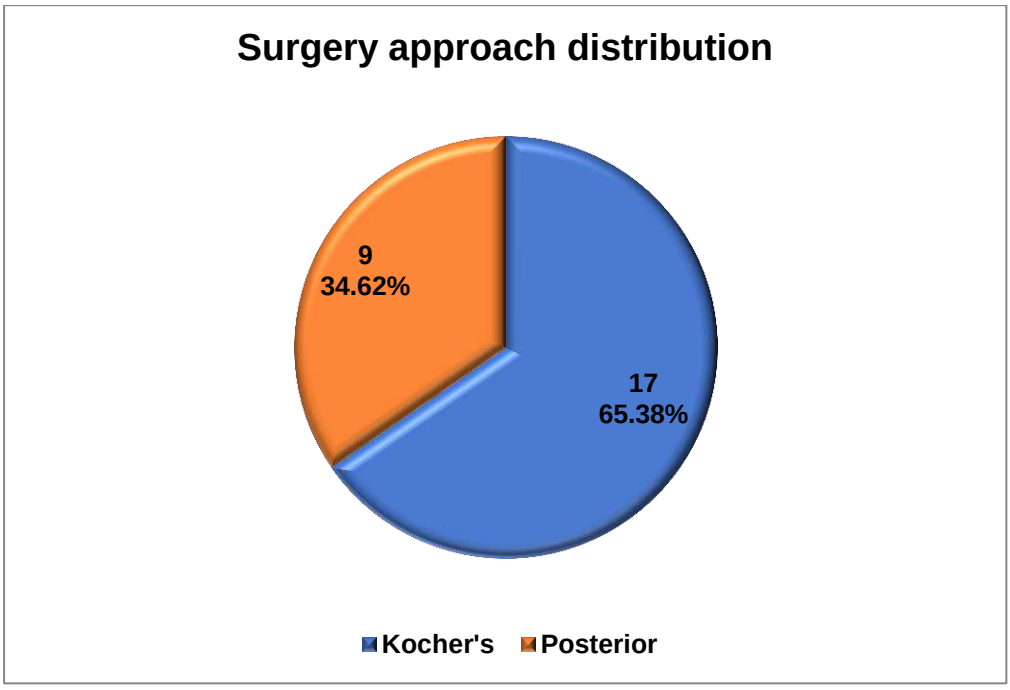


Figure 10:- Surgery approach distribution.

The surgical approach was Kocher's in 17 cases (65.38%) and posterior in 9 cases (34.62%). (Table 8, figure 10).

Table 9:- Distribution of demographics and diagnosis in Kocher's and posterior surgical approaches.

Demographics and clinical characteristics	Kocher's(n=17)	Posterior(n=9)	Total	P value
Age (years)				
21 to 30 years	3 (17.65%)	2 (22.22%)	5 (19.23%)	0.676§
31 to 40 years	3 (17.65%)	0 (0%)	3 (11.54%)	
41 to 50 years	4 (23.53%)	1 (11.11%)	5 (19.23%)	
51 to 60 years	3 (17.65%)	3 (33.33%)	6 (23.08%)	
>60 years	4 (23.53%)	3 (33.33%)	7 (26.92%)	
Mean ± SD	46.82 ± 16.2	53.33 ± 15.76	49.08 ± 16.04	0.335¶
Median(25th-75th percentile)	45(32-57)	59(47-64)	51(32.5-61.5)	
Range	25-82	28-69	25-82	
Gender				
Female	8 (47.06%)	6 (66.67%)	14 (53.85%)	0.429§
Male	9 (52.94%)	3 (33.33%)	12 (46.15%)	
Diagnosis				
Type III	10 (58.82%)	3 (33.33%)	13 (50%)	0.411§
Type IV	7 (41.18%)	6 (66.67%)	13 (50%)	

¶ Independent t test, § Fisher's exact test

Both Posterior approach as well as Kocher's approach had comparable distributions of age: (21 to 30 years: 17.65% in Kocher's vs. 22.22% in Posterior, 31 to 40 years: 17.65% vs. 0%, 41 to 50 years: 23.53% vs. 11.11%, 51 to 60 years: 17.65% vs. 33.33%, >60 years: 23.53% vs. 33.33%, respectively) (p value = 0.676).

Mean ± SD age was 46.82 ± 16.2 years in Kocher's approach and 53.33 ± 15.76 years in Posterior approach, with no significant difference between them (p value = 0.335).

Distribution of gender was also comparable between Kocher's vs. Posterior approaches (Female: 47.06% vs. 66.67%, Male: 52.94% vs. 33.33%) (p value = 0.429).

Distribution of type of fracture was comparable between Kocher's and Posterior approaches (Type III: 58.82% in Kocher's vs. 33.33% in Posterior, Type IV: 41.18% vs. 66.67%, respectively) (p value = 0.411). (Table 9).

Table 10:- Descriptive statistics of duration of surgery(hours).

Variable	Mean ± SD	Median(25th-75th percentile)	Range
Duration of surgery(hours)	2.05 ± 0.49	1.88(1.667-2.458)	1.33-3.17

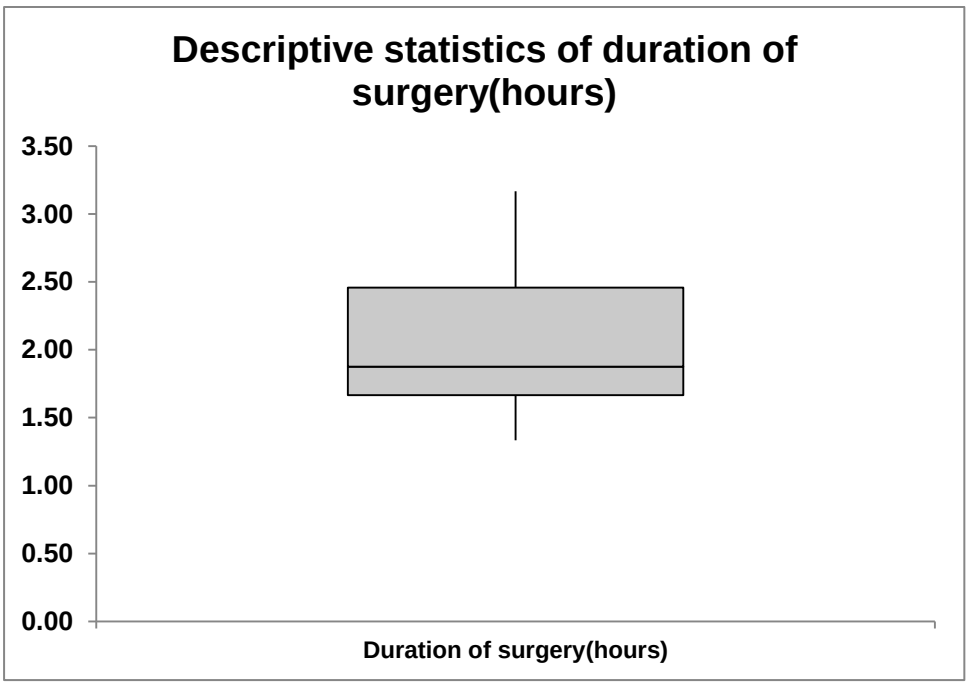


Figure 11:-Descriptive statistics of duration of surgery(hours).

The mean duration of surgery (hours) for the study subjects was 2.05 ± 0.49, with a median (25th-75th percentile) of 1.88 (1.667-2.458). (Table 10, figure 11).

Table 11:- Descriptive statistics of blood loss(mL).

Variable	Mean ± SD	Median(25th-75th percentile)	Range
Blood loss(mL)	61.35 ± 35.6	50(30-75)	30-150

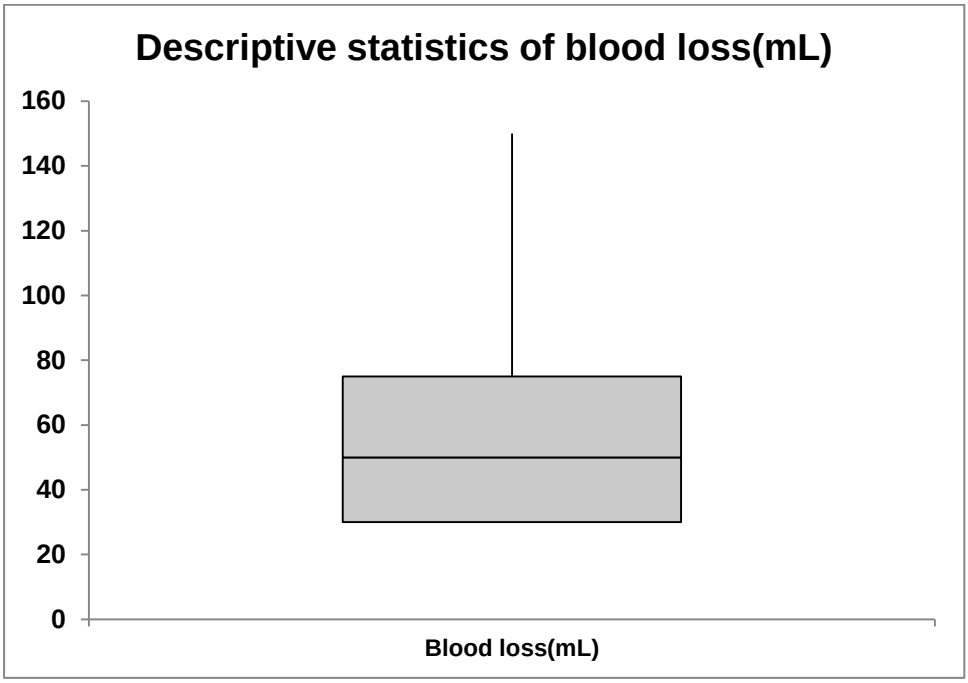


Figure 12:-Descriptive statistics of blood loss(mL).

The mean blood loss (mL) of the study subjects was 61.35 ± 35.6, with a median (25th-75th percentile) of 50 (30-75). (Table 11, figure 12).

Table 12:- Complication distribution.

Complication	Frequency	Percentage
None	22	84.61%
Heterotopic ossification	1	3.85%
Stiff elbow	3	11.54%
Total	26	100.00%

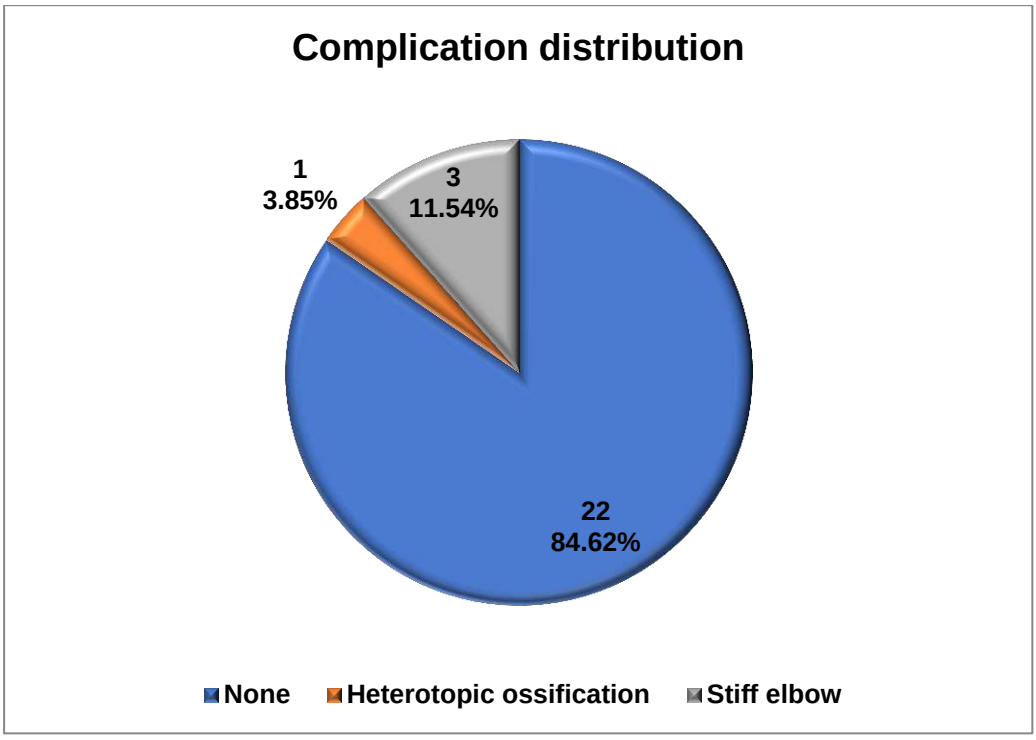


Figure 13:- Complication distribution.

The complications were distributed as follows: 22 cases (84.62%) had no complications, 3 cases (11.54%) had a stiff elbow, and 1 case (3.85%) had heterotopic ossification. (Table 12, figure 13).

Table 13:- Distribution of surgery related parameters in Kocher's and Posterior surgical approaches

Surgery related parameters	Kocher's (n=17)	Posterior (n=9)	Total	P value
Duration of surgery (hours)				
Mean ± SD	1.82 ± 0.36	2.49 ± 0.42	2.05 ± 0.49	0.0003¶
Median (25th-75th percentile)	1.75 (1.5-1.917)	2.5 (2.333-2.667)	1.88 (1.667-2.458)	
Range	1.33-2.67	1.67-3.17	1.33-3.17	
Blood loss (mL)				
Mean ± SD	43.82 ± 20.73	94.44 ± 34.86	61.35 ± 35.6	<.0001¶
Median (25th-75th percentile)	30(30-50)	75(75-100)	50(30-75)	
Range	30-100	50-150	30-150	
Complication				
None	14 (82.35%)	8 (88.89%)	22 (84.61%)	1§
Heterotopic ossification	1 (5.88%)	0 (0%)	1 (3.85%)	
Stiff elbow	2 (11.76%)	1 (11.11%)	3 (11.54%)	

¶ Independent t test, § Fisher's exact test

Both Posterior approach and Kocher's approach had comparable distribution of complications. (None: 82.35% in Kocher's vs. 88.89% in Posterior, Heterotopic ossification: 5.88% vs. 0%, Stiff elbow: 11.76% vs. 11.11%, respectively) (p value = 1).

Significant differences were observed in surgery-related parameters between two approaches. Mean ± SD duration of surgery was significantly lower in Kocher's approach (1.82 ± 0.36 hours) compared to Posterior approach (2.49 ± 0.42 hours) (p value = 0.0003). Similarly, mean ± SD blood loss was significantly lower in Kocher's approach (43.82 ± 20.73 mL) compared to Posterior approach (94.44 ± 34.86 mL) (p value < 0.0001) (Table 13).

Table 14:- Comparison of maximum elbow flexion(^{0}) between immediate post-op, post-op 3 and 6 months.

Maximum elbow flexion (^{0})	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Mean ± SD	114.23 ± 8.57	129.73 ± 7.05	131.31 ± 7.72	<.0001†
Median (25th-75th percentile)	116.5 (108-120)	131 (126.25-135)	134 (130-135)	Immediate post-op vs At 3 months:<0.0001
Range	100-130	115-142	110-142	Immediate post-op vs At 6 months:<0.0001 At 3 months vs At 6 months:0.104

† Repeated measure ANOVA

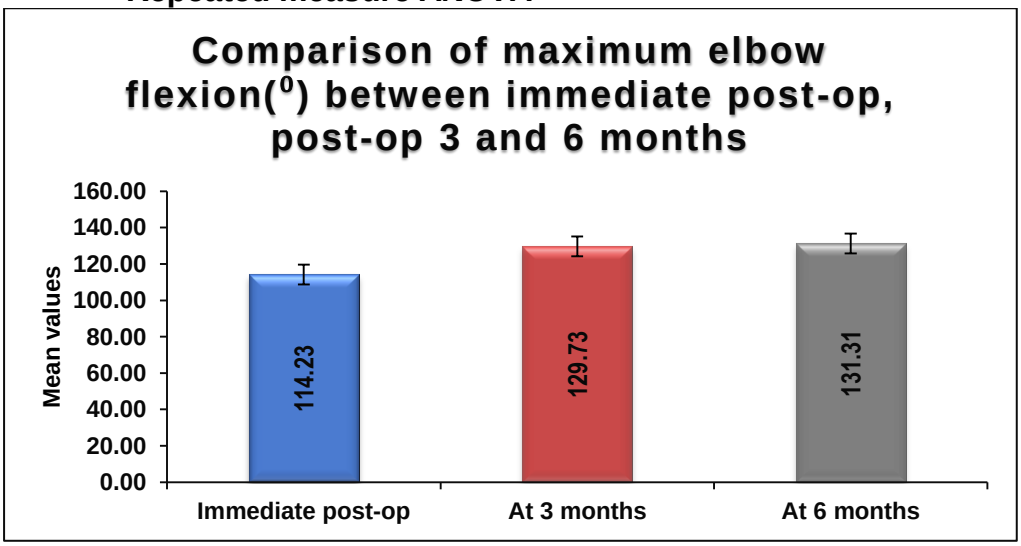


Figure 14:-Comparison of maximum elbow flexion(^{0}) between immediate post-op, post-op 3 and 6 months.

The maximum elbow flexion (^{0}) of the study subjects improved over time. The mean ± SD was 114.23 ± 8.57 immediately post-op, 129.73 ± 7.05 at 3 months, and 131.31 ± 7.72 at 6 months ($p < 0.0001$). The comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), while the difference between 3 months and 6 months was not significant ($p = 0.104$). (Table 14, figure 14).

Table 15:-Comparison of elbow extension deficit(^{0}) between immediate post-op, post-op 3 and 6 months.

Elbow extension deficit(^{0})	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Mean ± SD	68.15 ± 9.47	11 ± 10.25	6.5 ± 6.95	<.0001† Immediate post-op vs at 3 months:<0.0001 Immediate post-op vs at 6 months:<0.0001 At 3 months vs At 6 months:0.0003
Median(25th-75th percentile)	68 (62.25-74)	9 (2.5-17.5)	5 (0-13)	
Range	45-82	0-32	0-24	

† **Repeated measure ANOVA**

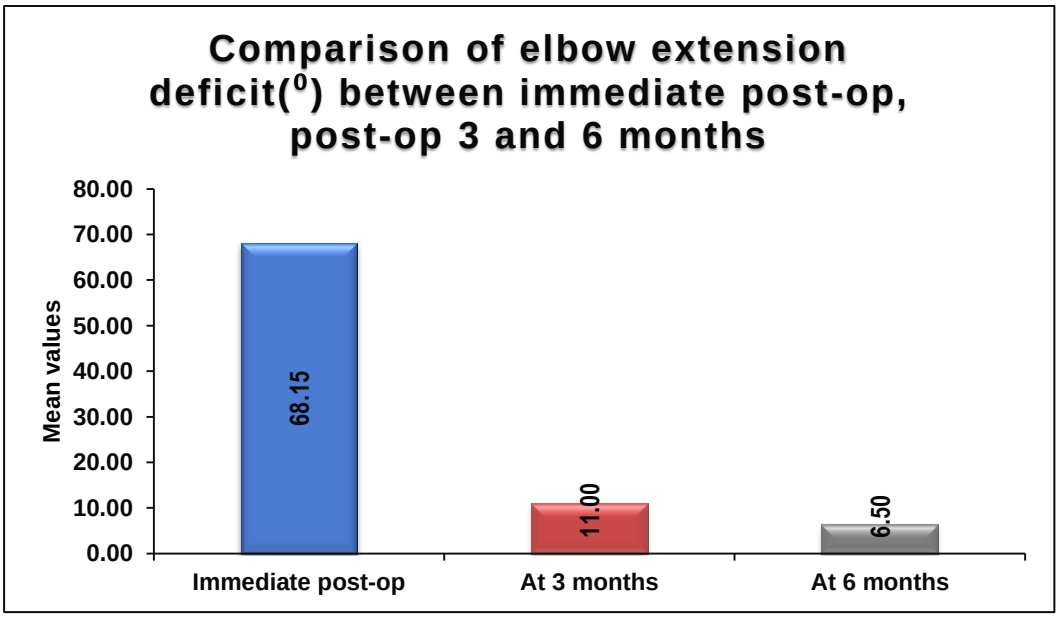


Figure 15:-Comparison of elbow extension deficit(^{0}) between immediate post-op, post-op 3 and 6 months.

The elbow extension deficit (^{0}) of the study subjects improved significantly over time. The mean ± SD was 68.15 ± 9.47 immediately post-op, 11 ± 10.25 at 3 months, and 6.5 ± 6.95 at 6 months ($p < 0.0001$). Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p = 0.0003$). (Table 15, figure 15).

Table 16:-Comparison of supination(^{0}) between immediate post-op, post-op 3 and 6 months.

Supination(^{0})	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Mean ± SD	39.77 ± 9.61	71.38 ± 14.28	75.88 ± 12.68	<.0001† Immediate post-op vs at 3 months:<0.0001 Immediate post-op vs at 6 months:<0.0001 At 3 months vs at 6 months:0.0002
Median (25th-75th percentile)	41 (32-45.5)	73 (61.5-83.75)	74 (68-88)	
Range	20-60	30-92	45-92	

† **Repeated measure ANOVA**

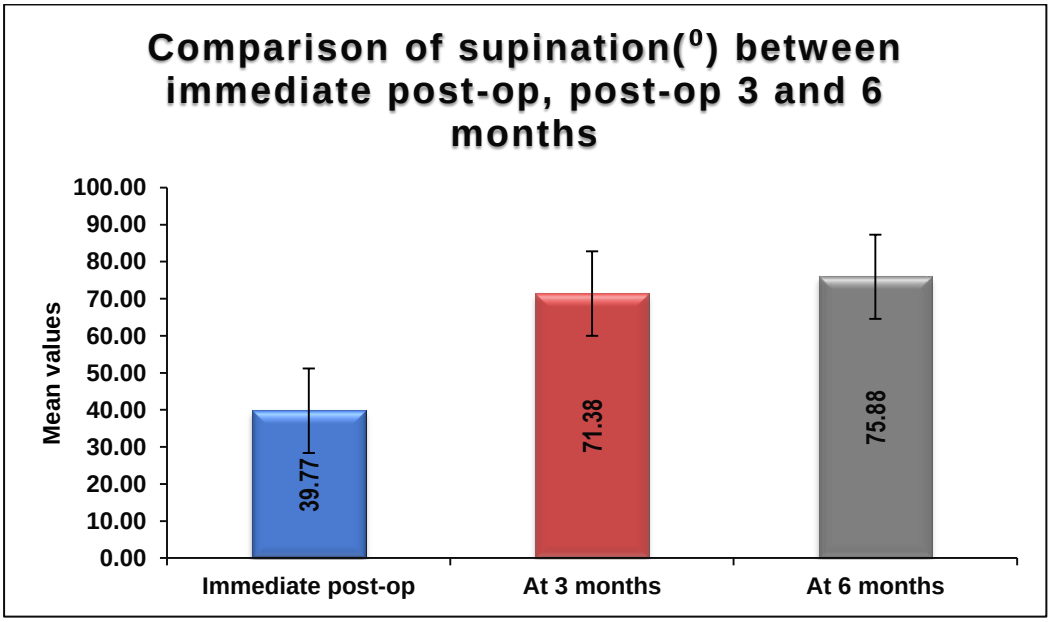


Figure 16:-Comparison of supination(^{0}) between immediate post-op, post-op 3 and 6 months.

The supination (^{0}) of the study subjects improved significantly over time. The mean ± SD was 39.77 ± 9.61 immediately post-op, 71.38 ± 14.28 at 3 months, and 75.88 ± 12.68 at 6 months ($p < 0.0001$). Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p = 0.0002$). (Table 16, figure 16).

Table 17:-Comparison of pronation(^{0}) between immediate post-op, post-op 3 and 6 months.

Pronation(^{0})	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Mean ± SD	28.88 ± 6.9	70.69 ± 11.22	75.04 ± 9.57	<.0001† Immediate post-op vs at 3 months:<0.0001 Immediate post-op vs at 6 months:<0.0001 at 3 months vs at 6 months:<0.0001
Median(25th-75th percentile)	27.5 (25-32.75)	73 (63.5-78)	78 (70.5-81.75)	
Range	18-46	44-90	48-90	

† **Repeated measure ANOVA**

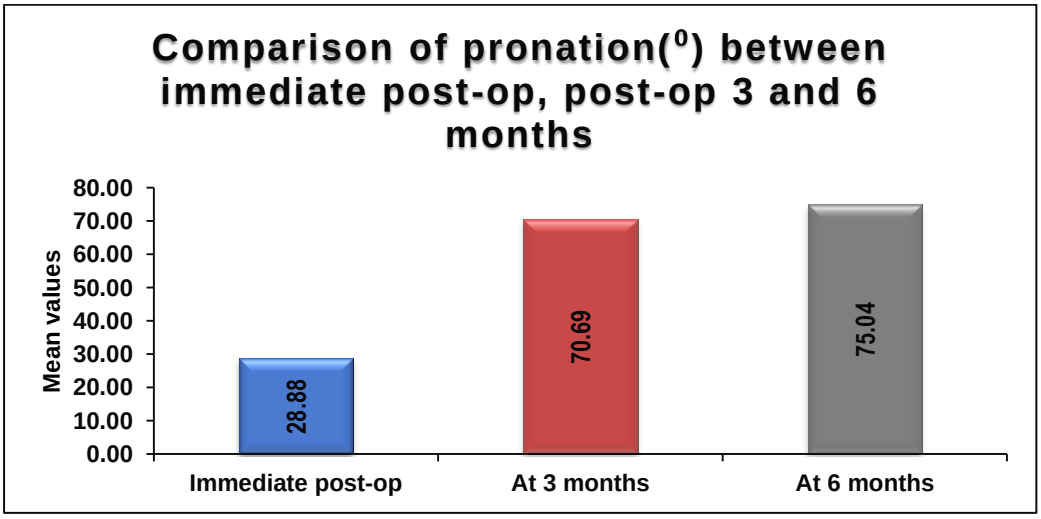


Figure 17:-Comparison of pronation(^{0}) between immediate post-op, post-op 3 and 6 months.

The pronation (^{0}) of the study subjects improved significantly over time. The mean ± SD was 28.88 ± 6.9 immediately post-op, 70.69 ± 11.22 at 3 months, and 75.04 ± 9.57 at 6 months ($p < 0.0001$). Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p < 0.0001$). (Table 17, figure 17)

Table 18:-Comparison of pain between immediate post-op, post-op 3 and 6 months.

Pain	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
None	0 (0%)	20 (76.92%)	22 (84.62%)	Immediate post-op vs at 3 months:<0.0001* Immediate post-op vs at 6 months:<0.0001* at 3 months vs at 6 months:<0.0001*
Mild	4 (15.38%)	6 (23.08%)	4 (15.38%)	
Moderate	14 (53.85%)	0 (0%)	0 (0%)	
Severe	8 (30.77%)	0 (0%)	0 (0%)	
Total	26 (100%)	26 (100%)	26 (100%)	

* **Bhapkar test**

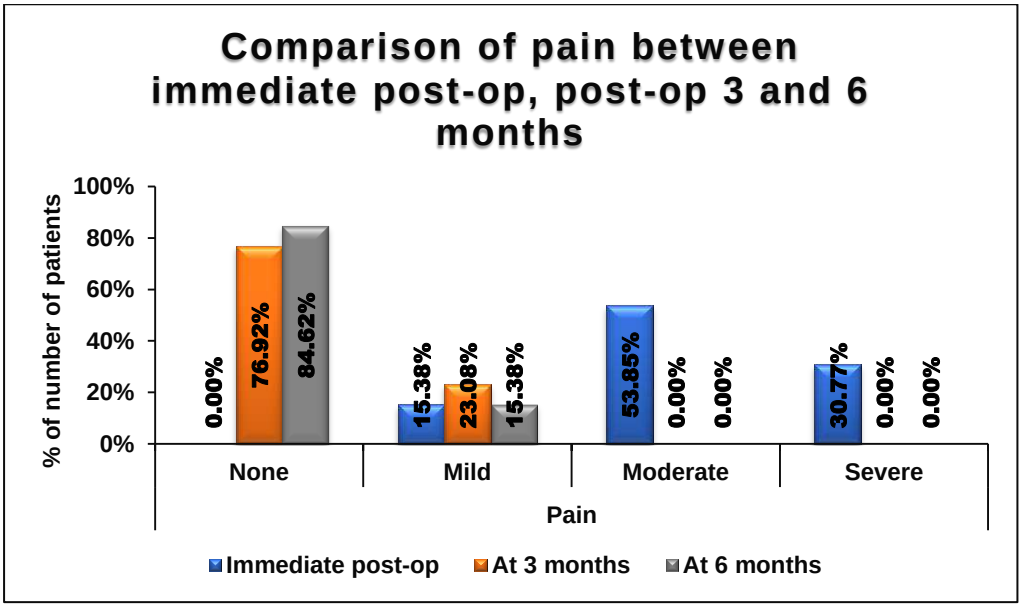


Figure 18:-Comparison of pain between immediate post-op, post-op 3 and 6 months.

The pain levels of the study subjects improved significantly over time. Immediately post-op, 0 cases (0%) reported no pain, 4 cases (15.38%) reported mild pain, 14 cases (53.85%) reported moderate pain, and 8 cases (30.77%) reported severe pain. At 3 months, 20 cases (76.92%)

reported no pain, 6 cases (23.08%) reported mild pain, and no cases reported moderate or severe pain. At 6 months, 22 cases (84.62%) reported no pain, 4 cases (15.38%) reported mild pain, and no cases reported moderate or severe pain ($p < 0.0001$ for all comparisons).

Comparisons showed significant improvement in pain levels from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$). (Table 18, figure 18).

Table 19:-Comparison of motion arc(^{0}) between immediate post-op, post-op 3 and 6 months.

Motion arc(^{0})	Immediate post-op(n=26)	At 3 months(n=26)	At 6 months(n=26)	P value
Mean ± SD	46.08 ± 16.9	118.73 ± 15.48	124.81 ± 13.04	<.0001† Immediate post-op vs at 3 months:<0.0001 Immediate post-op vs at 6 months:<0.0001 at 3 months vs at 6 months:0.0001
Median(25th-75th percentile)	48.5 (32.25-56.75)	122 (110-130)	130 (119-134.75)	
Range	18-85	88-142	86-142	

† **Repeated measure ANOVA**

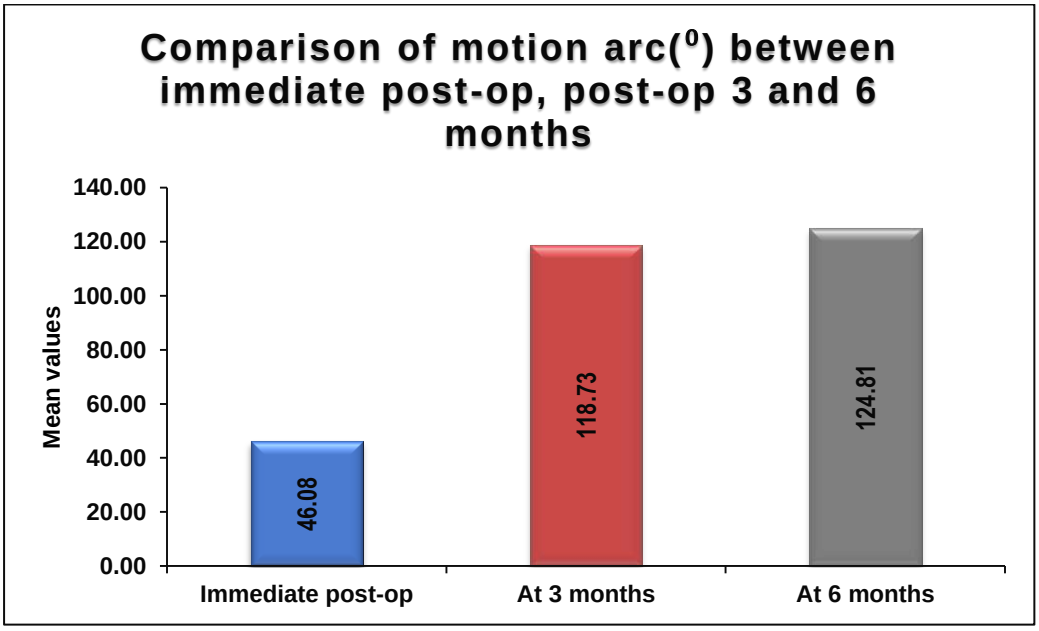


Figure 19:-Comparison of motion arc(^{0}) between immediate post-op, post-op 3 and 6 months.

The motion arc (^{0}) of the study subjects improved significantly over time. The mean ± SD was 46.08 ± 16.9 immediately post-op, 118.73 ± 15.48 at 3 months, and 124.81 ± 13.04 at 6 months ($p < 0.0001$). Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p = 0.0001$). (Table 19, figure 19).

Table 20:-Comparison of elbow joint stability between immediate post-op, post-op 3 and 6 months.

Stability	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Stable	26 (100%)	26 (100%)	26 (100%)	NA
Total	26 (100%)	26 (100%)	26 (100%)	

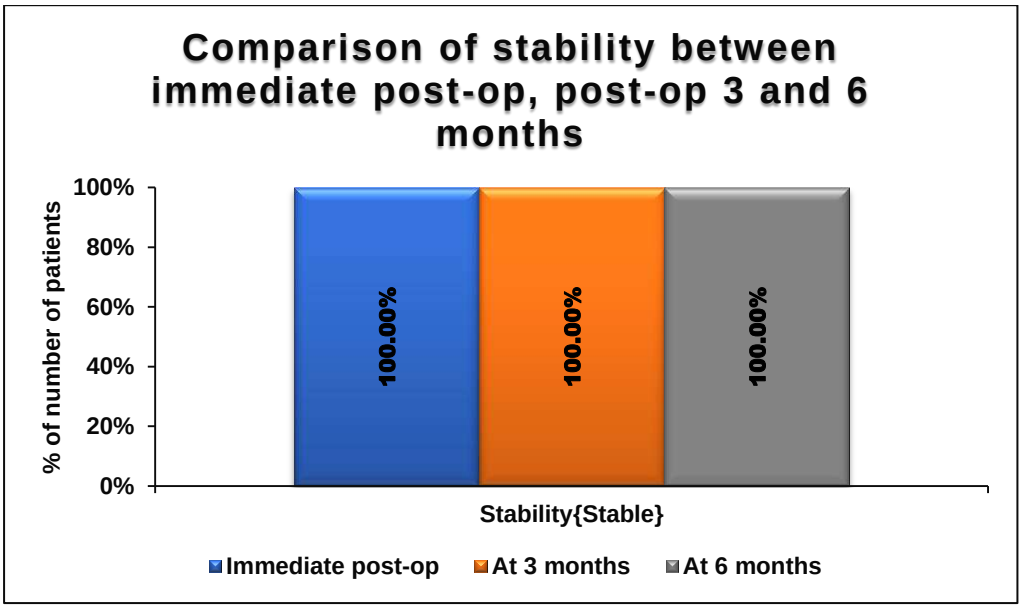


Figure 20:-Comparison of elbow joint stability between immediate post-op, post-op 3 and 6 months.

The stability of the elbow joint in subjects remained consistent over time. All 26 cases (100%) had stable elbow joint immediately post-op, at 3 months, and at 6 months, with no change observed and therefore no p-value available for comparison. (Table 20, figure 20).

Table 21:-Comparison of ADL score between immediate post-op, post-op 3 and 6 months.

ADL score	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Mean ± SD	5.38 ± 4.88	23.27 ± 3.45	24.81 ± 0.98	<.0001‡ Immediate post-op vs at 3 months:<0.0001 Immediate post-op vs at 6 months:<0.0001 at 3 months vs at 6 months:0.683
Median (25th-75th percentile)	5 (0-10)	25 (25-25)	25 (25-25)	
Range	0-15	15-25	20-25	

‡ **Friedman test**

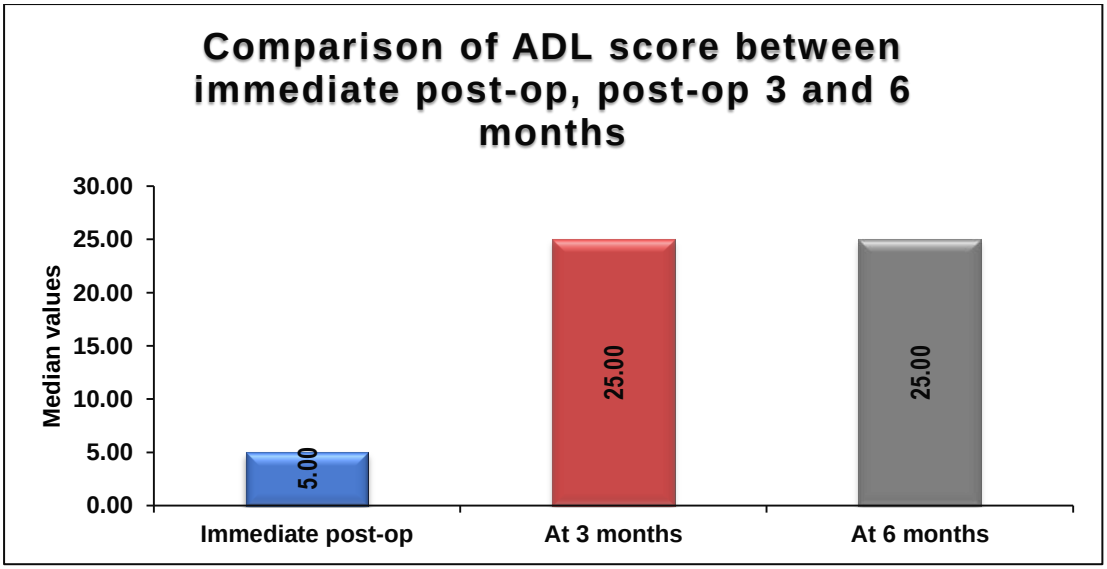


Figure 21:-Comparison of ADL score between immediate post-op, post-op 3 and 6 months.(non-parametric variable)

The ADL (Activities of Daily Living) scores of the study subjects improved significantly over time. The median (25th-75th percentile) ADL score was 5 (0-10) immediately post-op, 25 (25-25) at 3 months, and 25 (25-25) at 6 months ($p < 0.0001$). Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), while the difference between 3 months and 6 months was not significant ($p = 0.683$). The range of ADL scores was 0-15 immediately post-op, 15-25 at 3 months, and 20-25 at 6 months. (Table 21, figure 21).

Table 22:-Comparison of Mayo Elbow Performance Score (MEPS) between immediate post-op, post-op 3 and 6 months.

Mayo Elbow Performance Score (MEPS)	Immediate post-op (n=26)	At 3 months (n=26)	At 6 months (n=26)	P value
Poor	22 (84.62%)	0 (0%)	0 (0%)	Immediate post-op vs at 3 months:<0.0001* Immediate post-op vs at 6 months:<0.0001* at 3 months vs at 6 months:<0.0001*
Fair	4 (15.38%)	3 (11.54%)	0 (0%)	
Good	0 (0%)	3 (11.54%)	4 (15.38%)	
Excellent	0 (0%)	20 (76.92%)	22 (84.62%)	
Mean ± SD	37.69 ± 18.23	94.23 ± 10.46	97.31 ± 6.67	<.0001† Immediate post-op vs at 3 months:<0.0001 Immediate post-op vs at 6 months:<0.0001 at 3 months vs at 6 months:0.098
Median(25th-75th percentile)	37.5 (16.25-50)	100 (95-100)	100 (100-100)	
Range	15-70	70-100	75-100	

*** Bhapkar test, † Repeated measure ANOVA**

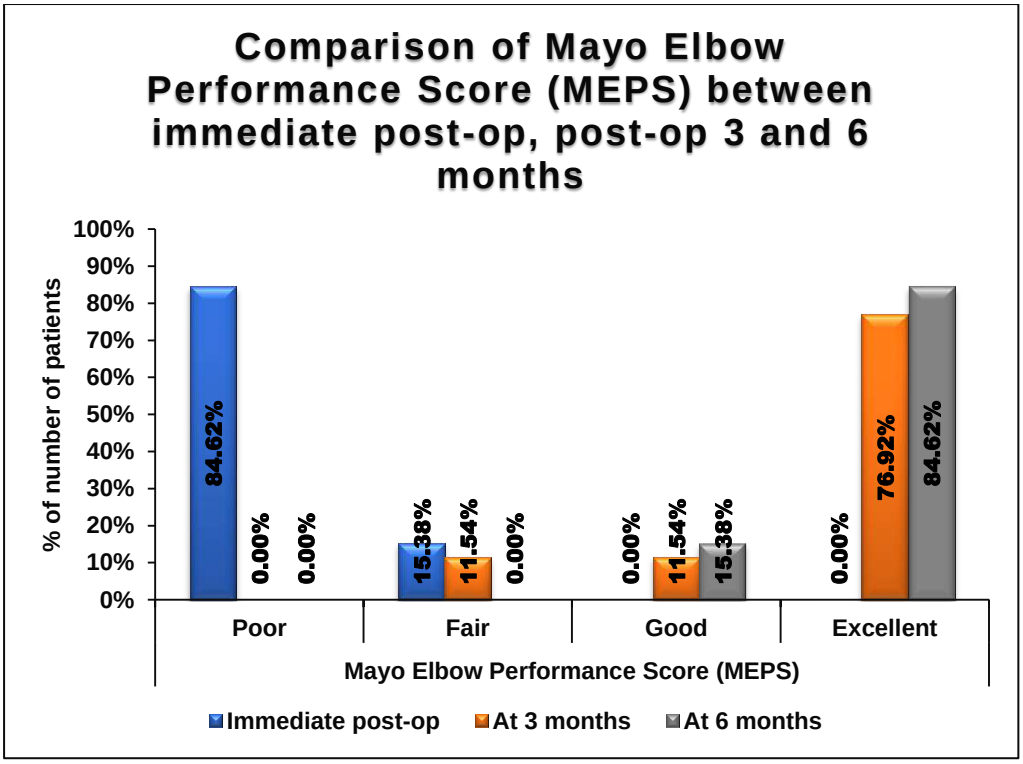


Figure 22:-Comparison of Mayo Elbow Performance Score (MEPS) between immediate post-op, post-op 3 and 6 months.

The Mayo Elbow Performance Score (MEPS) improved significantly over time. Immediately post-op, 22 cases (84.62%) had poor scores, 4 cases (15.38%) had fair scores, and no cases had good or excellent scores, with a mean ± SD of 37.69 ± 18.23. At 3 months, no cases had poor scores, 3 cases (11.54%) had fair scores, 3 cases (11.54%) had good scores, and 20 cases (76.92%) had excellent scores, with a mean ± SD of 94.23 ± 10.46. At 6 months, no cases had poor or fair scores, 4 cases (15.38%) had good scores, and 22 cases (84.62%) had excellent scores, with a mean ± SD of 97.31 ± 6.67. Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$). (Table 22, figure 22).

Table 23:-Immediate post-op period functional outcomes in Kocher's and Posterior surgical approaches

Immediate post-op period outcomes	Kocher's (n=17)	Posterior (n=9)	Total	P value
Pain				
Mild	4 (23.53%)	0 (0%)	4 (15.38%)	0.076§
Moderate	10 (58.82%)	4 (44.44%)	14 (53.85%)	
Severe	3 (17.65%)	5 (55.56%)	8 (30.77%)	
Stability				
Stable	17 (100%)	9 (100%)	26 (100%)	NA
Mayo Elbow Performance Score (MEPS)				
Poor	13 (76.47%)	9 (100%)	22 (84.62%)	0.263§
Fair	4 (23.53%)	0 (0%)	4 (15.38%)	
Mean ± SD	45.29 ± 17.09	23.33 ± 10	37.69 ± 18.23	0.002¶
Median(25th-75th percentile)	50(40-50)	15(15-35)	37.5 (16.25-50)	
Range	15-70	15-35	15-70	
Maximum elbow flexion(^{0})				
Mean ± SD	117.53 ± 7.5	108 ± 7.09	114.23 ± 8.57	0.004¶
Median(25th-75th percentile)	118(116-121)	108(102-110)	116.5 (108-120)	
Range	100-130	100-123	100-130	
Elbow extension deficit(^{0})				
Mean ± SD	64.88 ± 9.54	74.33 ± 5.7	68.15 ± 9.47	0.012¶
Median(25th-75th percentile)	64(60-70)	74(70-80)	68(62.25-74)	
Range	45-82	68-82	45-82	
Supination(^{0})				
Mean ± SD	42.82 ± 9.84	34 ± 6.14	39.77 ± 9.61	0.023¶
Median(25th-75th percentile)	44(41-49)	32(28-39)	41(32-45.5)	
Range	20-60	26-43	20-60	
Pronation(^{0})				
Mean ± SD	29.88 ± 7.72	27 ± 4.85	28.88 ± 6.9	0.321¶
Median(25th-75th percentile)	28(25-34)	26(24-30)	27.5(25-32.75)	
Range	18-46	20-37	18-46	
Motion arc(^{0})				
Mean ± SD	52.65 ± 16.37	33.67 ± 9.55	46.08 ± 16.9	0.004¶
Median(25th-75th	53(48-61)	31(27-40)	48.5 (32.25-56.75)	

percentile)				
Range	18-85	20-49	18-85	
ADL score				
Mean ± SD	7.35 ± 4.72	1.67 ± 2.5	5.38 ± 4.88	0.004**
Median(25th-75th percentile)	10(5-10)	0(0-5)	5(0-10)	
Range	0-15	0-5	0-15	

¶ Independent t test, ** Mann Whitney test, § Fisher's exact test

Both Posterior approach and Kocher's approach had comparable distribution of pain (Mild: 23.53% in Kocher's vs. 0% in Posterior, Moderate: 58.82% vs. 44.44%, Severe: 17.65% vs. 55.56%, respectively) (p value = 0.076). Distribution of Mayo Elbow Performance Score (MEPS) was also comparable (Poor: 76.47% vs. 100%, Fair: 23.53% vs. 0%, respectively) (p value = 0.263).

In immediate post-op period, stability was 100% in both Kocher's and Posterior groups.

No significant difference was observed in immediate post-op pronation between Kocher's (29.88 ± 7.72°) and Posterior (27 ± 4.85°) (p value = 0.321).

Significant differences were observed in other immediate post-op outcomes between Kocher's and Posterior approaches (p value < 0.05).

Mean ± SD maximum elbow flexion, supination and motion arc were significantly higher in Kocher's (117.53 ± 7.5°, 42.82 ± 9.84°, 52.65 ± 16.37°) compared to Posterior (108 ± 7.09°, p value = 0.004; 34 ± 6.14°, p value = 0.023; 33.67 ± 9.55°, p value = 0.004). Mean ± SD elbow extension deficit was significantly lower in Kocher's (64.88 ± 9.54°) than Posterior (74.33 ± 5.7°, p value = 0.012).

Significant differences were also seen in ADL score and MEPS. Median (25th–75th percentile) ADL score was higher in Kocher's (10 (5–10)) vs. Posterior (0 (0–5), p value = 0.004). Mean ± SD MEPS was also higher in Kocher's (45.29 ± 17.09) vs. Posterior (23.33 ± 10, p value = 0.002) (Table 23).

Table 24:- Functional outcomes at 3 months in Kocher's and Posterior surgical approaches

Outcome at 3 months	Kocher's (n=17)	Posterior (n=9)	Total	P value
Pain				
None	14 (82.35%)	6 (66.67%)	20 (76.92%)	0.628§
Mild	3 (17.65%)	3 (33.33%)	6 (23.08%)	
Stability				
Stable	17 (100%)	9 (100%)	26 (100%)	NA
Mayo Elbow Performance Score (MEPS)				
Fair	1 (5.88%)	2 (22.22%)	3 (11.54%)	0.535§
Good	2 (11.76%)	1 (11.11%)	3 (11.54%)	
Excellent	14 (82.35%)	6 (66.67%)	20 (76.92%)	
Mean ± SD	96.18 ± 8.93	90.56 ± 12.61	94.23 ± 10.46	0.198¶
Median(25th-75th percentile)	100(100-100)	95(85-100)	100(95-100)	
Range	70-100	70-100	70-100	
Maximum elbow flexion(^{0})				
Mean ± SD	132.18 ± 5.82	125.11 ± 7.13	129.73 ± 7.05	0.012¶
Median(25th-75th percentile)	134 (129-135)	128 (120-130)	131 (126.25-135)	
Range	118-142	115-135	115-142	
Elbow extension deficit(^{0})				
Mean ± SD	8.53 ± 9.51	15.67 ± 10.49	11 ± 10.25	0.091¶
Median(25th-75th percentile)	5(0-12)	12(8-26)	9(2.5-17.5)	
Range	0-30	4-32	0-32	
Supination(^{0})				
Mean ± SD	75.53 ± 15.1	63.56 ± 8.71	71.38 ± 14.28	0.039¶
Median(25th-75th percentile)	78(70-84)	60(58-72)	73(61.5-83.75)	
Range	30-92	50-74	30-92	
Pronation(^{0})				
Mean ± SD	73.71 ± 10.67	65 ± 10.49	70.69 ± 11.22	0.058¶
Median (25th-75th percentile)	76(71-78)	68(60-70)	73(63.5-78)	
Range	44-90	45-80	44-90	
Motion arc(^{0})				
Mean ± SD	123.65 ± 14.12	109.44 ± 14.2	118.73 ± 15.48	0.023¶

Median(25th-75th percentile)	127 (115-134)	110 (100-122)	122(110-130)	
Range	88-142	90-128	88-142	
ADL score				
Mean ± SD	24.12 ± 2.64	21.67 ± 4.33	23.27 ± 3.45	
Median(25th-75th percentile)	25(25-25)	25(20-25)	25(25-25)	0.067**
Range	15-25	15-25	15-25	

¶ Independent t test, ** Mann Whitney test, § Fisher's exact test

Both Posterior approach and Kocher's approach had comparable distributions of pain (None: 82.35% in Kocher's vs. 66.67% in Posterior, Mild: 17.65% vs. 33.33%, respectively) (p value = 0.628). Distribution of Mayo Elbow Performance Score (MEPS) was also comparable (Fair: 5.88% in Kocher's vs. 22.22% in Posterior, Good: 11.76% vs. 11.11%, Excellent: 82.35% vs. 66.67%, respectively) (p value = 0.535).

At 3 months, stability was 100% in both Kocher's and Posterior groups.

No significant difference was observed in 3-month outcomes for elbow extension deficit (**mean ± SD**: 8.53 ± 9.51° in Kocher's vs. 15.67 ± 10.49° in Posterior, p value = 0.091); pronation (°) (**mean ± SD**: 73.71 ± 10.67° vs. 65 ± 10.49°, p value = 0.058); ADL score (**median (25th–75th percentile)**:25 (25–25) vs. 25 (20–25), p value = 0.067) and MEPS (**mean ± SD**: 96.18 ± 8.93 vs. 90.56 ± 12.61, p value = 0.198).

Significant differences were observed at 3 months in maximum elbow flexion, supination, and motion arc with significantly higher values in Kocher's (132.18 ± 5.82°, 75.53 ± 15.1°, 123.65 ± 14.12°) compared to Posterior (125.11 ± 7.13°, p value = 0.012; 63.56 ± 8.71°, p value = 0.039; 109.44 ± 14.2°, p value = 0.023) (Table 24).

Table 25:- Functional outcomes at 6 months in Kocher's and Posterior surgical approaches

Outcome at 6 months	Kocher's (n=17)	Posterior (n=9)	Total	P value
Pain				
None	15 (88.24%)	7 (77.78%)	22 (84.62%)	0.591§
Mild	2 (11.76%)	2 (22.22%)	4 (15.38%)	
Stability				
Stable	17 (100%)	9 (100%)	26 (100%)	NA
Mayo Elbow Performance Score (MEPS)				
Good	2 (11.76%)	2 (22.22%)	4 (15.38%)	0.591§
Excellent	15 (88.24%)	7 (77.78%)	22 (84.62%)	
Mean ± SD	97.65 ± 6.87	96.67 ± 6.61	97.31 ± 6.67	0.729¶
Median(25th-75th percentile)	100(100-100)	100(100-100)	100(100-100)	
Range	75-100	85-100	75-100	
Maximum elbow flexion(^{0})				
Mean ± SD	133.65 ± 7.17	126.89 ± 7.06	131.31 ± 7.72	0.031¶
Median(25th-75th percentile)	135(132-138)	130(124-132)	134(130-135)	
Range	110-142	115-135	110-142	
Elbow extension deficit(^{0})				
Mean ± SD	4.94 ± 7.48	9.44 ± 4.9	6.5 ± 6.95	0.118¶
Median(25th-75th percentile)	0(0-9)	8(5-14)	5(0-13)	
Range	0-24	2-15	0-24	
Supination(^{0})				
Mean ± SD	79.47 ± 12.67	69.11 ± 10.11	75.88 ± 12.68	0.045¶
Median (25th-75th percentile)	84(72-89)	68(62-74)	74(68-88)	
Range	45-92	58-90	45-92	
Pronation(^{0})				
Mean ± SD	77.24 ± 8.53	70.89 ± 10.54	75.04 ± 9.57	0.109¶
Median (25th-75th percentile)	80(74-82)	74(66-78)	78(70.5-81.75)	
Range	58-90	48-82	48-90	
Motion arc(^{0})				
Mean ± SD	128.71 ± 13.03	117.44 ± 9.91	124.81 ± 13.04	0.033¶

Median(25th-75th percentile)	134(124-136)	118(110-122)	130(119-134.75)	
Range	86-142	103-132	86-142	
ADL score				
Mean ± SD	24.71 ± 1.21	25 ± 0	24.81 ± 0.98	0.467**
Median(25th-75th percentile)	25(25-25)	25(25-25)	25(25-25)	
Range	20-25	25-25	20-25	

¶ Independent t test, ** Mann Whitney test, § Fisher's exact test

Both Posterior approach and Kocher's approach had comparable distributions of pain (None: 88.24% in Kocher's vs. 77.78% in Posterior, Mild: 11.76% vs. 22.22%, respectively) (p value = 0.591). Distribution of Mayo Elbow Performance Score (MEPS) was also comparable (Good: 11.76% in Kocher's vs. 22.22% in Posterior, Excellent: 88.24% vs. 77.78%, respectively) (p value = 0.591).

At 6 months, stability was 100% in both Kocher's and Posterior groups.

No significant differences were observed in 6-month outcomes for elbow extension deficit (mean ± SD: 4.94 ± 7.48° in Kocher's vs. 9.44 ± 4.9° in Posterior, p value = 0.118); pronation (mean ± SD: 77.24 ± 8.53° vs. 70.89 ± 10.54°, p value = 0.109); ADL score (median (25th–75th percentile): 25 (25–25) in both Kocher's and Posterior, p value = 0.467) and MEPS (mean ± SD: 97.65 ± 6.87 vs. 96.67 ± 6.61, p value = 0.729).

Significant differences were observed at 6 months in maximum elbow flexion, supination and motion arc, with higher values in Kocher's (133.65 ± 7.17°, 79.47 ± 12.67°, 128.71 ± 13.03°) compared to Posterior (126.89 ± 7.06°, p value = 0.031; 69.11 ± 10.11°, p value = 0.045; 117.44 ± 9.91°, p value = 0.033) (Table 25).

DISCUSSION

In about 20% of elbow injuries, radial head and neck fractures are prevalent. In injuries involving the elbow joint such as fracture of the coronoid process and ligament injures involving the medial collateral ligament and lateral ulnar collateral ligament, the radial head serves the primary function of stabilizing the joint.[76]

In this regard we studied the functional outcomes in patients with radial head fractures (Mason type III and IV), who underwent RHA in the immediate post-operative period as well as at 3 months and 6 months.

Age

The mean age of patients in our study was 49.08 ± 16 years. This was comparable to a randomized control trial study by Mulders MA et al[77] (2021) on surgical v/s conservative management of mason type 2 radial head fractures, where the mean age of study population was 50 years (interquartile range 45.5-58.0). In the study by Kaur N et al,[62] the mean age of 391 patients with radial head fracture was 48.4 years. Ajrawat et al[71] 2021 reported that the mean age of 25 patients with comminuted closed RHF was 41.23 ± 8.2 years (range 21-55 years). Kulkarni V et al[65] found the mean age of patients to be 40.3 years in their study on 30 patients with radial head fracture who underwent RHA. In the study by Schnetzke M et al,[66] on 78 patients who underwent monopolar RHA, the patients' mean age was 59.2 years.

Foroohar A et al[69] 2022 reported the mean age of distribution of 53.9 ± 15.3 years in their study of RHA over 9-year period. Similarly, Mercer DM et al[78] 2022 reported the mean age of distribution as 61.3 years (range, 26-85) in their retrospective study which evaluated the clinical and radiographic outcomes of RHA in patients with radial head pathology.

Grewal R et al[79] 2006 reported a mean age of 54 ± 14.6 years in their study of outcomes following RHA over a three year period and Chen A

et al[52] 2021 reported a mean age of 42.7 ± 13.3 years in their study on long term outcomes of RHA.

The reason for increased incidence of fractures in this age group is due to a decrease in the bone mineral density as the age progresses. These changes in bone mineral density and microarchitecture of the skeletal structure make the radial head more prone to fractures with increasing age.[80]

Gender

The gender distribution in the present study showed that 14 patients (53.85%) were female, and 12 patients (46.15%) were male. Comparing to other studies, Baek CN et al[81] 2020 reported that there were 11 females and 13 males in their study population.

Songy CM et al[82] 2021, in their study of 114 patients who underwent radial head replacement for radial head fractures, found majority were females- 64 (56%) and 50 (44%) were males.

This was also comparable to a study by Foroohar A et al[69] 2022 which reported females (60.6%) as majority in their subjects. Similarly, Mulders MA et al[77] 2021 reported that 25 patients (56%) were females while 20 cases (44%) were males out the total 45 patients.

Females in the older age group are more prone to radial head fractures, as their bone quality decreases with increasing age due to osteoporosis.[80]

Occupation

The occupation distribution of our patients was, 13 (50.00%) were homemakers, 4 cases (15.38%) were businessmen, 2 cases (7.69%) were engineers, 2 cases (7.69%) were students, and 1 case (3.85%) each was a mechanic, property dealer, retired government employee, retired laborer, and shop owner. This was comparable to study reported by Varma N et al[83] 2022, where majority of the patients were

students 5 (20%), followed by daily wage workers 2 (16%), homemakers, sportsmen and farmers 2 (12%) each, and other occupations were milkman, postman, drivers and others.

In the study by Alkheraiji AF et al,[84] out of patients with RHF, most of the patients (78.3%) were laborers, involving jobs such as plumbers, electric technicians, and carpenters. Office workers constituted 13.3% of total patients, like students, accountants, or company employees; and 5(8.3%) were driver.

Schnetzke et al[66] reported that among 78 patients who underwent monopolar RHA, where 50 (69.4%) were employed and 22(30.6%) were retired/unemployed.

Mode of Injury

In our study high energy trauma as a consequence of RTA was the commonest cause of fractures as seen in 80.77% of cases, others were domestic falls (15.38%) and assault (3.58%). Comparing our studies to other studies we found a similar scenario.

El Sallakh S et al[85] 2013 found that most of the subjects with radial head fractures had fall (11cases) as the mode of injury whereas only one patient had RTA as the mode of injury out of the 12 cases.

Even, Kulkarni V et al[65] 2020 found RTA as the major cause of radial head fractures (18 cases) followed by fall (12 cases) out of the 30 patients

Ajrawat SS et al[71] 2023 also showed RTA as the commonest cause of fractures (14 cases) followed by fall (11 cases) out of 25 cases.

Fall on outstretched hand is also reported to be a common mode of injury in previous studies. Kaur N et al[62] found that the commonest mode of injury in most of the patients (68.4%) was fall on outstretched hand, followed by fall from height (>6 feet) (14%) and motor vehicle accident (9.2%).

In the study by Kadam et al,[64] on 18 patients with radial head fracture, the mode of injury was fall on an outstretched hand (n=8), road traffic accident (n=6), and history of assault (n=4). Kandel M et al[70] found that 96 patients with radial head fracture, the commonest mode of injury was fall on an outstretched hand (54.55%), road traffic accident (27.27%), and assault (18.18%).

Diagnosis – fracture type

The distribution of Mason type of radial head fractures was type III in 13 cases (50.00%), type IV in 13 cases (50.00%) of our study.

This was comparable to study by Madhukar DV et al[86] 2019, which compared the functional outcomes of radial head excision arthroplasty and replacement arthroplasty. The distribution of Mason type of fractures in their study were type II fractures were 17 (51.51%) cases and type III fractures were 16(48.48%) out of the total number of 33 cases.

Another study by Kulkarni V et al[65] 2020, evaluated the clinical outcomes of RHA in comminuted radial head fractures, their distribution of Mason type of fractures out of the total of 30 cases were type III fractures - 22 (73.33%) and type IV fractures were 8 (26.67%) cases.

Lobo-Escolar L et al[67] 2021, studied the results of radial press fit arthroplasty in complex radial head fractures, Mason type IV fractures were 32 (71.1%) and type 3 were 13 (27.9%) out of 45 cases.

Ajrawat SS et al[71] 2023 reported 19 (76.00%) cases of type III and 6 (24.00%) of type IV fractures out 25 cases in their study of RHA for comminuted radial head fractures.

A comparison of type of fractures in our study and other studies is shown in Table 26.

Table 26: comparison of type of fractures in different studies

Study	Type II fractures	Type III fractures	Type IV fractures
Present study	-	13 (50.00%)	13 (50.00%)
Madhukar DV et al[86] 2019	17 (51.51%)	16(48.48%)	-
Kulkarni V et al[65] 2020	-	22 (73.33%)	8 (26.67%)
Lobo-Escolar L et al[67] 2020	-	13 (27.9%)	32 (71.1%)
Ajrawat SS et al[71] 2023	-	19 (76.00%)	6 (24.00%)

Associated injuries

In our study a total of 11 cases (57.7%) had associated ligamentous injuries or fractures. Among the associated injuries, 8 cases (30.77%) had LCL injuries, 8 cases (30.77%) had olecranon fractures, 4 cases (15.38%) had MCL injuries, and 2 cases (7.69%) had coronoid fractures.

In other studies, Kodde IF et al80 reported that out of 46 patients, coronoid fracture was present in 14 (30.4%) patients, carpal fracture 12(26.1%), distal radial fracture in 4(8.7%), Proximal ulna fracture in 4(8.7%), Coronoid + LCL injury (dislocation) in 3(6.5%), SL dislocation 2(4.3%), UCL injury in 1(2.2%), LCL injury in 2(4.3%), Capitellum injury in 2(4.3%), DRUJ dislocation in 1(2.2%), and humeral fracture in 1(2.2%) patient.

In the study by Kulkarni et al,[65] out of 30 patients with radial fractures, the associated injuries were elbow dislocation + LCL injury +MCL injury in 8 (26.66 %) patients, LCL injury in 5 (16.66%), MCL injury in 2 (6.66 %), and olecranon fracture in 2 (6.66 %) patients.

Moghaddam et al[63] conducted study on 85 patients with radial fracture and associated injuries, out of which fracture of coronoid process was present in 59.4% patients, followed by avulsion of radial collateral ligament in 28.1%, avulsion of ulnar collateral ligament (20.3%), capsular avulsion (14.1%), fracture of the olecranon (7.8%), Fracture of

the shaft of ulna (6.3%), fracture of the scaphoid (1.6%) and fracture of the thumb in 1.6% patients.

Ajrawat et al[71] 2021 reported that out of 25 patients with comminuted closed RHF, associated injuries were lateral collateral ligament injury in 4 (16.00%) patients, medial collateral ligament injury in 3 (12.00%), elbow dislocation and LCL injury and MCL injury in 3 (12.00%), and olecranon fracture in 2 (8.00%) patients.

van Riet RP et al[28] reported that among 333 radial head fractures, the associated injuries included fractures at elbow (88.6%), elbow dislocation (51.13%), lateral collateral ligament (39.77%), collateral ligament + lateral collateral ligament (22.7%), medial distal radioulnar joint (11.36%), and medial collateral ligament (5.6%).

In the study by Vavken P et al[87] on 1,323 patients with RHF, 33% of the patients had associated injuries, with commonest injury being lateral collateral ligaments injury (51 %), followed by injury to the capitellum (22%).

Surgical approach

The distribution of surgical approach used for RHA was Kocher's in 17 cases (65.38%) and posterior in 9 cases (34.62%). This was comparable to other studies such as one by Contreras-Joya et al[88] 2015, they used Kocher's method of surgical approach in radial head fractures, for fracture of olecranon posterior approach was used and medial approach method of Kasparyan and Hotchkiss was used in 2 cases where it was not possible to reconstruct the coronoid process laterally. Mulders MA et al[77] 2021 used Kocher's surgical approach in all their patients. Similarly, Varma N et al[83] 2022 used Kocher's surgical approach to perform radial head excision and radial head replacement.

The most frequently used method of surgical approach is Kocher's and Kaplan's method. Kocher's method is most popular technique, where

the radial head visualization is obtained by approaching between the anconeus and extensor carpi ulnaris muscles.

In Kaplan's method, developing the plane between the extensor digitorum communis and the extensor carpi radialis longus provides excellent and adequate visualization of proximal radius and coronoid process.[9,83]

Duration of surgery

We found that the mean duration of surgery (hours) for the study subjects was 2.05 ± 0.49, with a median (25th-75th percentile) of 1.88 (1.667-2.458) which was comparable to a study done by Weissman JP et al[89] 2022 where the mean duration of surgery was 111.6 ± 59 minutes.

Al-Burdeni S et al[90] conducted study on 17 patients with radial head fractures, who underwent RHA. The mean duration of the surgery was 96.8 minutes. The increased mean duration of surgery was high in our study in comparison to other studies because of 15 cases (57.7%) having associated injuries such as a fracture of olecranon or coronoid requiring fixation with ORIF or an associated ligamentous injury requiring repair. For 11 cases (42.3%) with an isolated fracture of the radial head, the operative time was significantly lesser in our study.

Likewise, Yan M et al[91] conducted study on 20 patients with "terrible triad of the elbow characterized by a Mason type-III RHF". The mean duration of radial head replacement was 193.2 ± 15.53 minutes, which was similar to our study.

Duration of surgery in Kocher's surgical approach

In the present study, the mean duration of surgery of the patients who underwent Kocher's technique was 1.82 ± 0.36 hours.

In other studies, in which Kocher's technique was used, Contreras-Joya M et al[88] reported that the mean duration of surgery was 100±56.8 minutes. In the study by Guerra et al,[92] 19 patients received

treatment with Kocher's approach; the mean duration of procedure was 81.66 minutes.

Duration of surgery in Posterior surgical approach

In the present study, the mean duration of surgery of the patients who underwent Posterior technique was 2.49 ± 0.42 hours.

In the study by Li D et al,[93] 76 patients were treated for terrible triad injuries (TTIs), out of which 44 underwent modified posterior approach (MPA). The median duration of surgery was 171.73 ± 80.68 minutes.

Range of motion

Elbow Flexion

In our study, the mean of maximum degree of elbow flexion found in our patients was 114.23 ± 8.57 immediately post-op, 129.73 ± 7.05 at 3 months, and 131.31 ± 7.72 at 6 months ($p < 0.0001$).

This was comparable to reports by Baek CS et al[81] 2020, the mean range of motion for flexion was 132.7° ± 7.4° (mean follow up -58.9 months (range, 27–163 months)).

Study by Songy CE et al[82] 2021 had an average follow up period of 6.5 months, mean of range of motion reports at the earliest follow up was (2-16 years), 133 (60–150) degree for flexion.

Elbow flexion in Kocher's surgical approach

In the present study, the mean of maximum degree of elbow flexion of the patients who underwent Kocher's technique was 117.53 ± 7.5.

Among other studies which performed Kocher's technique for radial head arthroplasty, Varma N et al[83] 2022 reported the mean the functional outcome of elbow at 6 month of follow up, the mean of range of motion in the radial head replacement group and radial head excision group was 126.9 ± 11.3 v/s 121.5 ± 19.6 degree for flexion respectively ($p < 0.05$).

Mulders MA et al[77] 2021 reported follow up of functional outcomes at 3 months, 6 months and 12 months. The median for range motion in operated group (radial head replacement) was 135 (130-140) º at 3 months, 140 (132-140) º at 6 months and 140 (134-144) º at 12 months for flexion.

Elbow flexion in Posterior surgical approach

In the present study, the mean of maximum degree of elbow flexion of the patients who underwent Posterior technique was 108 ± 7.09.

In other studies, Das SP et al[94] reported that in 13 patients who had radial head fractures were treated with posterior approach, flexion-extension arc was calculated postoperatively at 1 year, the mean value of which was 128.46 ± 4.27 degrees.

Elbow extension deficit

The mean elbow extension deficit degree in our study was 68.15 ± 9.47 immediately post-op, 11 ± 10.25 at 3 months, and 6.5 ± 6.95 at 6 months ($p < 0.0001$) which was comparable to reports by Baek CS et al[81] 2020, the mean range of motion for extension was 4.7° ± 10.8° at last the follow-up. Songy CE et al[82] 2021 reported their mean extension deficit of 14 (0– 90) degree.

Elbow extension deficit in Kocher's surgical approach

In the present study, the mean elbow extension deficit degree of the patients who underwent Kocher's technique was 64.88 ± 9.54.

In other studies, which performed Kocher’s technique for radial head arthroplasty, Varma N et al[83] 2022 found their mean of extension deficit in the radial head replacement group and radial head excision group to be 11.7 ± 12.7 v/s 16.5 ± 15.5 degree respectively (p=0.932). Whereas Mulders MA et al[77] 2021 reported the median for range motion in operated group (radial head replacement) to be 7 (0-15) degree at 3 months, 9 (3-15) at 6 months and 5 (0-10) at 12 months for extension deficit.

Elbow extension deficit in Posterior surgical approach

In the present study, the mean elbow extension deficit degree of the patients who underwent Posterior technique was 74.33 ± 5.7.

Supination and pronation

The mean of elbow supination in the present study was 39.77 ± 9.61 immediately post-op, 71.38 ± 14.28 at 3 months, and 75.88 ± 12.68 at 6 months ($p < 0.0001$) and mean of pronation was 28.88 ± 6.9 immediately post-op, 70.69 ± 11.22 at 3 months, and 75.04 ± 9.57 at 6 months ($p < 0.0001$).

This was comparable to reports by Baek CS et al[81] 2020, their mean pronation degree was 76.2° ± 10.6° and 77.5° ± 5.3° of supination. Songy CE et al[82] 2021 reported mean degree of pronation to be 78 (0–90), and 66 (0–90) degree for supination.

Supination and pronation in Kocher's surgical approach

In the present study, in patients who underwent Kocher's technique, the mean of elbow supination was 42.82 ± 9.84 immediately post-op, 75.53 ± 15.1 at 3 months, and 79.47 ± 12.67 at 6 months ($p < 0.0001$) and mean of pronation was 29.88 ± 7.72 immediately post-op, 73.71 ± 10.67 at 3 months, and 77.24 ± 8.53 at 6 months.

In similar other studies which used Kocher's technique, Mulders MA et al[77] 2021 reported the median for pronation was 87 (85-90) at 3 months, 89 (85-90) at 6 months, 85 (82-86) at 12 months. The median of supination degree was 89 (85-90) at 3 months, 87 (85-90) at 6 months, and 85 (80-90) at 12 months. Krishna MV et al[95] reported that out of 21 patients who underwent RHA through Kocher's technique, the mean of supination was 83.33 and the mean of pronation was 83.81. Schnetzke et al found that among 78 patients who underwent monopolar RHA through Kocher's technique, the median values of pronation was 70 and that of supination was 80. In a similar study,

Varma N et al[83] 2022 found the mean of pronation in the radial head replacement group and radial head excision group to be 71.4 ± 14.2 v/s 61.5 ± 17.8 degree respectively ($p< 0.05$), and mean of supination was 67.4 ± 14.1 v/s 63.0 ± 16.2 degree respectively ($p < 0.05$).

Supination and pronation in Posterior surgical approach

In the present study, in patients who underwent posterior technique, the mean of elbow supination was 34 ± 6.14 immediately post-op, 63.56 ± 8.71 at 3 months, and 69.11 ± 10.11 at 6 months ($p < 0.0001$) and mean of pronation was 27 ± 4.85 immediately post-op, 65 ± 10.49 at 3 months, and 70.89 ± 10.54 at 6 months.

In other studies, Das SP et al[94] reported that in 13 patients who had radial head fractures were treated with posterior approach, supination-pronation arc was calculated postoperatively at 1 year, the mean value of which was 133.92 ± 4.04 degrees.

Pain

The pain levels of our patients improved significantly over time postoperatively which was evident in the immediate postoperative period where 14 cases (53.85%) reported moderate pain, followed by 8 cases (30.77%) reported severe pain, and 4 cases (15.38%) reported mild pain whereas at 3 months, majority of them (20 cases (76.92%)) reported no pain, 6 cases (23.08%) reported mild pain, and none of them reported moderate or severe pain. Results showed significant improvement in pain levels from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$).

This was comparable to other studies. Baek CS et al[81] 2020 reports the mean VAS score for pain was 0.6 ± 1.1 for 24 patients at last follow up, where patients had no pain, eight had mild pain, and one had moderate pain.

Songy CE et al[82] 2021 found in their recent follow up, out of 79% of patients, 48% had no pain, mild pain was reported in 42%, moderate pain in 8%, and severe pain in 3% of cases while Mercer DM et al[78] 2022 found that the mean visual analog scale for pain at rest was 0.9 (0-10), and for pain while unscrewing a bottle cap was 1.9 (0-10).

Pain in Kocher's surgical approach

The pain levels of our patients improved significantly over time postoperatively which was evident in the immediate postoperative period where 10 (58.82%) cases reported moderate pain, followed by 3 (17.65%) cases reported severe pain, and 4 (23.53%) cases reported mild pain, whereas at 3 months, majority of them [14 (82.35%) cases] reported no pain, 3 (17.65%) cases reported mild pain, and none of them reported moderate or severe pain. at 6 months, 15 (88.24%) cases reported no pain, and 2 (11.76%) cases had mild pain.

In similar studies in which Kocher's approach was used, Mulders MA et al[77] 2021 reported the median VAS scores was immediate preoperatively was 7, 1 at 3 months, 0 at 6 months, 0 at 12 months. Krishna MV et al reported that out of 21 patients who underwent RHA through Kocher's technique, 47% of patients showed chronic pain; the mean VAS score was 2.2.

Pain in Posterior surgical approach

The pain levels of our patients improved significantly over time postoperatively which was evident in the immediate postoperative period where 4 (44.44%) cases reported moderate pain, followed by 5 (55.56%) cases reported severe pain, whereas at 3 months, majority of them [6 (66.67%) cases] reported no pain, 3 (33.33%) cases reported mild pain. At 6 months, 7 (77.78%) cases reported no pain, and 2 (22.22%) cases had mild pain.

In the study by Das SP et al,[94] 13 patients who had radial head fractures were treated with posterior approach, VAS scores were calculated postoperatively at 1 year, the mean value of which was 2.16.

MEPS

The Mayo Elbow Performance Score (MEPS) is the most frequently utilized multi -dimensional tool for assessing the functional performance of the elbow specifically in all forms of elbow related pathology. It integrates the patient-based, subjective components of pain and function with the clinically observable characteristics of mobility and stability into a single score. The variables of pain, motion, stability and function are given the maximum weightings of 45%, 20%, 10% and 25%, respectively. The latent construct of overall elbow performance is indicated by the total score, which is derived from the scores in each of the four dimensions.[96,97]

We compared MEPS of elbow joint between immediate post-op, post-op 3 and 6 months which showed that 22 cases (84.62%) had poor scores and 4 cases (15.38%) had fair scores with a mean ± SD of 37.69 ± 18.23 and none had excellent scores in the immediate postoperative period. Whereas 20 cases (76.92%) had excellent scores, followed by 3 cases (11.54%) had fair scores, 3 cases (11.54%) had good scores with a mean ± SD of 94.23 ± 10.46 at 3 months. At 6 months, 4 cases (15.38%) had good scores, and 22 cases (84.62%) had excellent scores, with a mean ± SD of 97.31 ± 6.67. Comparisons showed significant improvement from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$).

Baek CS et al[81] 2020 reported on 24 cases of radial head replacements for complex radial head fractures at a mean follow up period of 58.4 months with excellent MEPS score in 14 patients (58.3%), good score in nine patients (37.5%), and poor score in one patient (4.2%) with mean MEPS score of 88.7 ± 11.5.

Ajrawat et al[71] 2021 reported that out of 25 patients with comminuted closed RHF, MEPS score was excellent (>95) in 20 (80%) patients,

good (75-94) in 3 (12%), fair (60-74) in 1 (4%), and poor (<60) in 1 (4%) patient.

MEPS score in Kocher's surgical approach

We compared MEPS of elbow joint between immediate post-op, post-op 3 and 6 months which showed that 13 (76.47%) cases had poor scores and 4 (23.53%) cases had fair score with a mean ± SD of 45.29 ± 17.09 and none had excellent scores in the immediate postoperative period. Whereas at 3 months, 14 (82.35%) cases had excellent scores, followed by 2 (11.76%) cases had good scores and 1 (5.88%) case had fair scores, with a mean ± SD of 96.18 ± 8.93. At 6 months, 15 (88.24%) cases had excellent scores and 2 (11.76%) cases had good score with a mean ± SD of 97.65 ± 6.87.

Among similar studies that used Kocher's technique for RHA, Varma N et al[83] 2022 compared the outcomes in radial head replacement group and radial head excision, the mean MEPS score was 65.32± 6.31 v/s 61.24± 7.12 (p=0.062) at immediate postop, 68.75± 5.39 v/s 64.24 ± 6.35 (p=0.072) at first month, 84.36 ±5.22 v/s 75.26 ±6.31 (p=0.033) at 3 months and 92.66 ±6.1 v/s 86.33± 7.55 (p=0.021) at 6 months. Out of 25 patients in replacement group 15 patients had poor score, 8 patients had fair score and 2 had good score in immediate post op, while 8 patients had good score, 8 had fair score, 7 had poor score and 2 had excellent score at 1st month of follow up. At 3 months, 10 had good score, 9 had excellent score, 5 had fair score and one had poor score while at 6 months 15 patients had excellent score, 8 had good score, 2 had fair score and none of them had poor score.

In a study by Contreras-Joya M et al[88] 2015, outcomes of RHA in 82 patients over 11 years was evaluated, their results in their follow up period of 1-11 years showed mean MPS score of 80.4±19.3. Excellent and good MEPS scores were seen in 35.8% and 35.8% respectively, fair score in 14.8% and poor score in 13.6% of cases.

Krishna MV et al reported that out of 21 patients who underwent RHA through Kocher's technique, MEPS score was used to assess functional outcomes. The mean values of MEPS score at 2 weeks, 12 weeks and 6 months were 81.19, 86.90, and 93.57, respectively.

Kadam V et al reported that in 21 patients who underwent RHA through Kocher's technique, MEPS score was used to assess functional outcomes, which showed excellent result in 13 (72%) patients, good results in 3 (17%), and fair result in 2 (11%) patients. No patient had poor result.

MEPS score in Posterior surgical approach

We compared MEPS of elbow joint between immediate post-op, post-op 3 and 6 months which showed that all 9 (100%) cases had poor scores with a mean ± SD of 23.33 ± 10 and none had excellent scores in the immediate postoperative period. Whereas 6 (66.67%) cases had excellent scores, followed by 2 (22.22%) cases had fair scores, 1 (11.11%) case had good scores with a mean ± SD of 90.56 ± 12.61 at 3 months. At 6 months, 2 (22.22%) cases had good scores, and 7 (77.78%) cases had excellent scores, with a mean ± SD of 96.67 ± 6.61.

Das SP et al[94] reported that in 13 patients who had radial head fractures were treated with posterior approach, MEPS scores were calculated postoperatively at 1 year, the mean value of which was 78.46 ± 8.26.

Li D et al[93] reported that among 44 patients who underwent posterior approach, the mean MEPS score was 96.82 ± 6.04, with excellent scores in 35 patients and good score in 9 patients.

ADL SCORE

The majority of young, healthy people are capable of performing most basic and routine chores known as activities of daily living (ADLs) without help. Inability in carrying out daily tasks might result in hazardous circumstances and a low quality of living. In order to identify

patients who need assistance, health care workers should be aware of the significance of assessing patients' activities of daily living (ADLs). The activity describes daily living activities in detail and emphasises how the interprofessional team evaluates ADLs to improve patient care and management.[98]

The median (25th-75th percentile) ADL score in our study was 5 (0-10) immediately post-op, 25 (25-25) at 3 months, and 25 (25-25) at 6 months ($p < 0.0001$) with significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), with no difference in improvement between 3 months and 6 months ($p = 0.683$).

In comparison among the previous studies, DASH score has been used for assessing ADL. The disability of Arm, Shoulder and Hand (DASH) questionnaire is a standardized assessment tool that gathers patient viewpoints regarding the state of their upper limbs[99] , so ADL score may be compared to DASH score.

In the study by Chen AC et al[52] 2021, which evaluated long term outcomes of RHA, the mean quick DASH score in their study of 2 year follow up was 12.2 ± 12.6 and 10 year follow – up was 14.1 ± 14.3 ($p= 0.306$)

ADL score in Kocher's surgical approach

The median (25th-75th percentile) ADL score in patients who underwent Kocher's technique was 10(5-10) immediately post-op, 25(25-25) at 3 months, and 25(25-25) at 6 months.

In similar studies that used Kocher's technique, Varma N et al[83] 2022 reported their mean DASH score in radial head replacement group at immediate postop to be 65.32 ± 6.31, 27.7± 7.3 at 1st month, 22.3± 8.5 at the 3rd month and 15.9 ±7.2 at 6 months of follow up. Kumar P et al[100] 2022 also reported their mean DASH score in the radial head prothesis group at 6 weeks to be 13.06±3.9, 10.66±3.2 at 3 months and 5.2±1.7 at 6 months.

ADL score in Posterior surgical approach

The median (25th-75th percentile) ADL score in patients who underwent Posterior technique was 0(0-5) immediately post-op, 25(20-25) at 3 months, and 25(25-25) at 6 months.

Das SP et al[94] reported that in 13 patients who had radial head fractures were treated with posterior approach, quickDASH score was used to assess activities of daily living. It was calculated postoperatively at 1 year, the mean value of which was 7.15 ± 2.96.

Complications

In our study, 22 cases (84.62%) had no complications, while 3 cases (11.54%) had a stiff elbow, and 1 case (3.85%) had heterotopic ossification. In comparison, Baek CS et al[81] 2020 reported 4 complications (16.7%) out of 24 patients in their study which evaluated the short to mid-term complications of RHA for complex radial head fractures comprising of major complications in two cases with a single case of stiffness along with “heterotopic ossification and progressive ulnar neuropathy” and other one showing severe stiffness after the follow up of 3 months after surgery. Two patients had minor complications, both having “transient ulnar neuropathy” which completely resolved after 4 months.

Songy CE et al[82] 2021 reported that 14 patients required radial head replacement revision or reoperation, 11 patients suffered other complications: 5 patients had wound infection, 3 had elbow instability, 2 had pain with retained implants, and one had fracture.

Mercer DM et al[78] 2022 reported 4 complications (7.6%) and 3 reoperations (5.7%) out of 52 patients.

Ajrawat et al[71] 2021 reported that out of 25 patients with comminuted closed RHF, complex regional pain syndrome was present in 1 (4%) and joint stiffness in 1 (4%) patient.

Schnetzke M et al[66] 2021 found that out of 78 patients who underwent monopolar RHA, the complications were painful loosening in 17 (28.8%), postoperative elbow stiffness [11 (14.1%)], ulnar nerve neuropathy [3 (3.8%)], radial nerve neuropathy [1 (1.3%)], loose bodies [1 (1.3%)] and complex regional pain syndrome [1 (1.3%)].

Moghaddam et al[63] found that among 85 patients with comminuted radial head fractures, who underwent RHA, complications were extensive periprosthetic ossification (n=11, 12.94%), neurolysis of the ulnaris nerve (n=1, 1.17%), neobursa (n=1, 1.17%), and extensive swelling and blistering (n=1, 1.17%).

Kulkarni V et al[65] reported that in 30 patients with radial head fracture who underwent RHA, CRPS and elbow joint stiffness were present in one patient each. In the study by Lobo-Escolar L et al,[67] on 45 patients with complex radial head fractures, who underwent treatment with RHA and press-fit radial head prosthesis, complications were present in 12(26.7%) patients: pain/instability (15.6%), synostosis (2.2%), and stiffness, ulnar pseudoarthrosis, and ulnar nerve dysfunction in 2.2% patients each.

Complications in Kocher's surgical approach

Out of 17 patients who underwent Kocher's technique, 14 (82.35%) cases had no complications, while 2 (11.76%) cases had stiff elbow, and 1 (5.88%) case had heterotopic ossification.

In similar studies, Varma N et al[83] 2022 reported only two complications out of 25 patients who had undergone radial head replacement for radial head fractures. Lans J et al[101] reported that in 18 patients who underwent RHA through Kocher's technique, 6 complications occurred, which were nonunion [3(16.67%)], implant irritation [2(11.11%)] and heterotopic ossification [1(5.5%)].

Krishna MV et al reported that out of 21 patients who underwent RHA through Kocher's technique, out of which 10(47.6%) had mild chronic

pain, followed by valgus laxity (9.5%), elbow stiffness (14.3%), and implant loosening (4.8%).

Complication in Posterior surgical approach

Out of 9 patients who underwent Kocher's technique, 8 (88.89%) cases had no complications, while 1 (11.11%) case had stiff elbow, and none had heterotopic ossification.

In the study by Das SP et al,[94] 13 patients who had radial head fractures were treated with posterior approach. Elbow stiffness and ulnar nerve neuropraxia developed in two patients. Li D et al[93] reported that among 44 patients who underwent posterior approach, there were no complications.

LIMITATIONS

The limitations regarding the present study were that it was single center and small sample size study which in turn may limit the generalizability of our findings.

SUMMARY AND CONCLUSION

This study was conducted in Department of Orthopaedics at Dayanand Medical College and Hospital, Ludhiana. 26 patients presented with radial head fractures (Mason type III and IV) planned for RHA were included in the study. Functional outcomes in the immediate post-operative period as well as at 3 months and 6 months were evaluated.

The key points of the summary are:

- The mean age of the study subjects was 49.08 ± 16 years, with a median (25th-75th percentile) of 51 years (32.5-61.5).
- Majority of the patients were (53.85%) were female and rest were (46.15%) were males.
- Based on the distribution of occupation majority (50%) were home makers.
- The distribution of Mason type of radial head fractures was type III in 13 cases (50.00%), type IV in 13 cases (50.00%).
- RTA was the commonest cause of fractures as seen in 80.77% cases. Others were domestic falls (15.38%) and assault (3.85%).
- Among the associated injuries, 8 cases (30.77%) had LCL injuries, 8 cases (30.77%) had olecranon fractures, 4 cases (15.38%) had MCL injuries, and 2 cases (7.69%) had coronoid fractures.
- Kocher's operative approach was followed in 17 cases (65.38%) and posterior approach in 9 cases (34.62%).
- The mean duration of surgery (hours) for the study subjects was 2.05 ± 0.49, with a median (25th-75th percentile) of 1.88 (1.667-2.458). The mean duration of surgery of the patients who underwent Kocher's surgical approach was 1.82 ± 0.36 hours and of Posterior surgical approach was 2.49 ± 0.42 hours.
- The mean blood loss (mL) of the study subjects was 61.35 ± 35.6, with a median (25th-75th percentile) of 50 (30-75).
- Patients significantly improved in the flexion range of motion from immediate post-op to 3 months ($p < 0.0001$) and from

immediate post-op to 6 months ($p < 0.0001$), while there was no significant difference in the improvement between 3 months and 6 months ($p = 0.104$).

- The mean of maximum degree of elbow flexion of the patients who underwent Kocher's surgical approach was 117.53 ± 7.5 and of Posterior surgical approach was 108 ± 7.09.
- Significant improvement was noted in elbow extension deficit from the immediate post-op period to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p = 0.0003$).
- The mean elbow extension deficit degree of the patients who underwent Kocher's surgical approach was 64.88 ± 9.54 and of Posterior surgical approach was 74.33 ± 5.7.
- There was significant improvement in the elbow supination of patients from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p = 0.0002$).
- In patients who underwent Kocher's surgical approach, the mean of elbow supination was 42.82 ± 9.84 immediately post-op, 75.53 ± 15.1 at 3 months, and 79.47 ± 12.67 at 6 months ($p < 0.0001$) and mean of pronation was 29.88 ± 7.72 immediately post-op, 73.71 ± 10.67 at 3 months, and 77.24 ± 8.53 at 6 months.
- In patients who underwent posterior surgical approach, the mean of elbow supination was 34 ± 6.14 immediately post-op, 63.56 ± 8.71 at 3 months, and 69.11 ± 10.11 at 6 months ($p < 0.0001$) and mean of pronation was 27 ± 4.85 immediately post-op, 65 ± 10.49 at 3 months, and 70.89 ± 10.54 at 6 months.
- Elbow pronation was significantly improved from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), as well as between 3 months and 6 months ($p < 0.0001$).

- Results showed significant improvement in pain levels from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$).
- In patients who underwent Kocher's surgical approach, in the immediate postoperative period where 10 (58.82%) cases reported moderate pain, followed by 3 (17.65%) cases reported severe pain, and 4 (23.53%) cases reported mild pain, whereas at 3 months, majority of them [14 (82.35%) cases] reported no pain, 3 (17.65%) cases reported mild pain, and none of them reported moderate or severe pain. at 6 months, 15 (88.24%) cases reported no pain, and 2 (11.76%) cases had mild pain.
- In patients who underwent posterior surgical approach, in the immediate postoperative period where 4 (44.44%) cases reported moderate pain, followed by 5 (55.56%) cases reported severe pain, whereas at 3 months, majority of them [6 (66.67%) cases] reported no pain, 3 (33.33%) cases reported mild pain. At 6 months, 7 (77.78%) cases reported no pain and 2 (22.22%) cases had mild pain.
- The mean range of motion arc was 46.08 ± 16.9 degrees immediately post-op, 118.73 ± 15.48 at 3 months, and 124.81 ± 13.04 at 6 months ($p < 0.0001$).
- All the 26 cases (100%) had a stable elbow joint immediately post-op, at 3 months, and at 6 months.
- The median (25th-75th percentile) ADL score was 5 (0-10) immediately post-op, 25 (25-25) at 3 months, and 25 (25-25) at 6 months ($p < 0.0001$) with significant improvement from immediate post-op to 3 months ($p < 0.0001$) and from immediate post-op to 6 months ($p < 0.0001$), with no difference in improvement between 3 months and 6 months ($p = 0.683$).
- The median (25th-75th percentile) ADL score in patients who underwent Kocher’s surgical approach was 10(5-10)

immediately post-op, 25(25-25) at 3 months, and 25(25-25) at 6 months.

- The median (25th-75th percentile) ADL score in patients who underwent Posterior surgical approach was 0(0-5) immediately post-op, 25(20-25) at 3 months, and 25(25-25) at 6 months.
- The mean of mean of MEPS score at immediate post op was 37.69 ± 18.23, at 3 months it was 94.23 ± 10.46 and was of 97.31 ± 6.67 at 6 months with significant improvement from immediate post-op to 3 months ($p < 0.0001$), from immediate post-op to 6 months ($p < 0.0001$), and between 3 months and 6 months ($p < 0.0001$).
- In patients who underwent Kocher's surgical approach, 13 (76.47%) cases had MEPS poor scores and 4 (23.53%) cases had fair score with a mean ± SD of 45.29 ± 17.09 and none had excellent scores in the immediate postoperative period. Whereas at 3 months, 14 (82.35%) cases had excellent scores, followed by 2 (11.76%) cases had good scores and 1 (5.88%) case had fair scores, with a mean ± SD of 96.18 ± 8.93. At 6 months, 15 (88.24%) cases had excellent scores and 2 (11.76%) cases had good score with a mean ± SD of 97.65 ± 6.87.
- In patients who underwent posterior surgical approach, all 9 (100%) cases had poor MEPS scores with a mean ± SD of 23.33 ± 10 and none had excellent scores in the immediate postoperative period. Whereas 6 (66.67%) cases had excellent scores, followed by 2 (22.22%) cases had fair scores, 1 (11.11%) case had good scores with a mean ± SD of 90.56 ± 12.61 at 3 months. At 6 months, 2 (22.22%) cases had good scores, and 7 (77.78%) cases had excellent scores, with a mean ± SD of 96.67 ± 6.61.
- In our study, 22 cases (84.62%) had no complications, while 3 cases (11.54%) had a stiff elbow, and 1 case (3.85%) had heterotopic ossification

- Out of 17 patients who underwent Kocher's surgical approach, 14 (82.35%) cases had no complications, while 2 (11.76%) cases had stiff elbow, and 1 (5.88%) case had heterotopic ossification. Out of 9 patients who underwent posterior surgical approach, 8 (88.89%) cases had no complications, while 1 (11.11%) case had stiff elbow.

CONCLUSION

In conclusion, RHA effectively restored the stability and congruency of the elbows with radial head fractures. There was a significant improvement in the range of motion involving flexion, extension deficit, supination and pronation during our follow up period with minimal complications. There was also a significant improvement in the ADL and MEPS scores during follow up of immediate post op, 3 months and 6 months – indicating improved quality of life after the surgery. The improvement was significantly more with Kocher's surgical approach as compared to posterior surgical approach in the immediate post-operative period – which became statistically comparable in the follow up period of 6 months.

FUTURE RECOMMENDATIONS

It is recommended to conduct a randomized control trial study with different management options. The clinical outcomes may be assessed for a larger subset of population.

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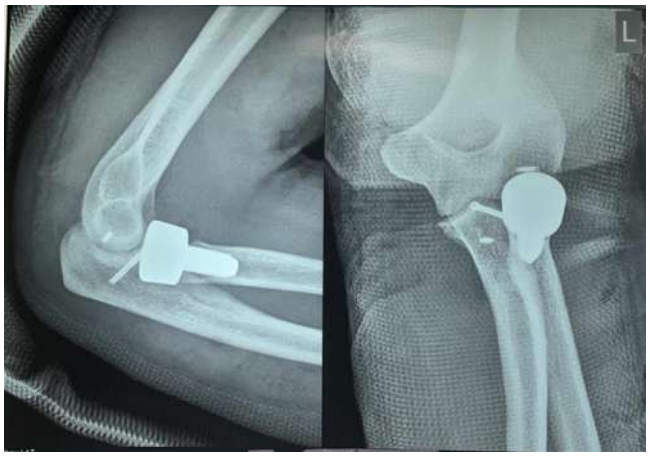
(a) (b)

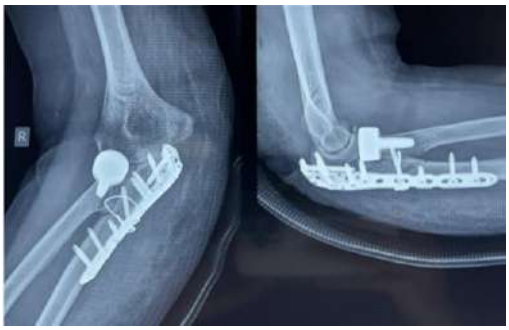
69y/f Homemaker with proximal ulna and radial head fracture (Mason type III) due to domestic fall (a) Pre-op x-ray (b) X-ray at 6 months follow-up. Mayo Elbow Performance score indicated excellent results

(a) (b) 

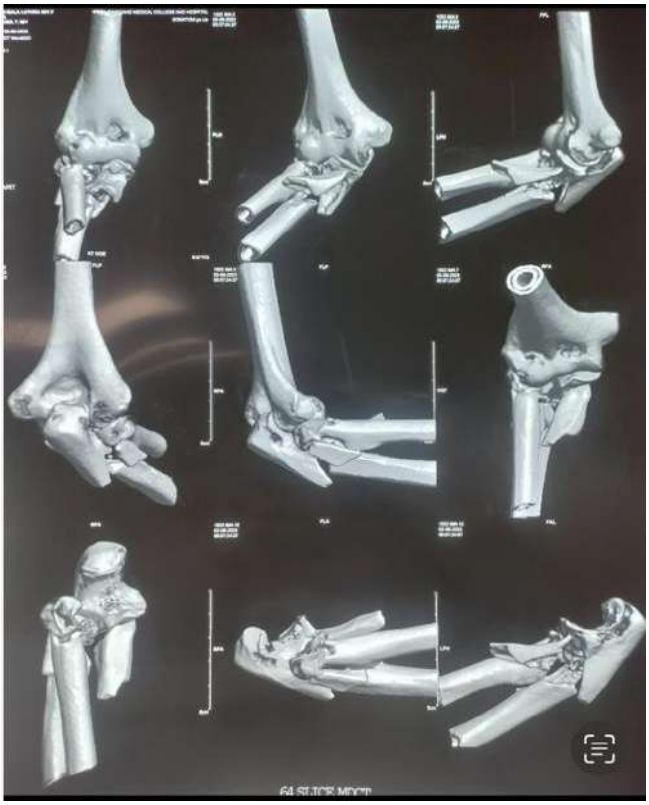
28y/m Engineer with radial head fracture dislocation (Mason type IV) due to road traffic accident with associated injury of the lateral collateral, medial collateral ligaments and fracture coronoid. (a) Pre-op x-ray (b) X-ray at 6 months follow-up. Mayo Elbow Performance score indicated excellent results

(a)

(b)



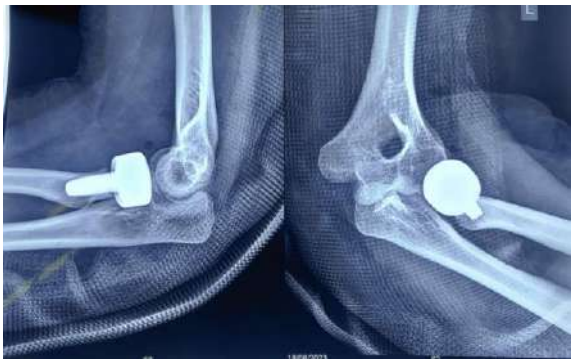
(c)



68y/f Homemaker with radial head (Mason type III) and proximal ulna fracture due to domestic fall (a),(c) Pre-op x-ray and CT films (b) X-ray at 6 months follow-up. Mayo Elbow Performance score indicated excellent results

(a)

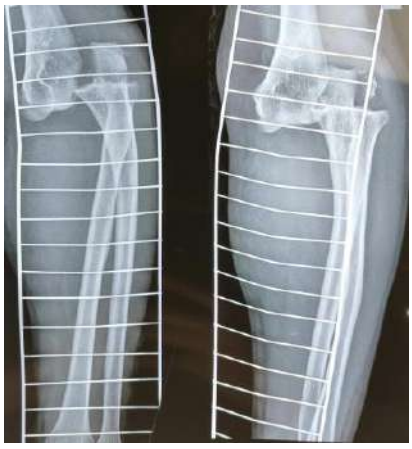
(b)



42y/f with radial head fracture (Mason type III) due to road traffic accident (a) Pre-op x-ray (b) X-ray at 6 months follow-up. Mayo Elbow Performance score indicated excellent results

(a) (b)

(c) (d)

(e)  (f)

52 y/m Businessman with radial head fracture dislocation (Mason type IV) (e) Pre-op x-ray (a),(b),(c),(d)Presenting with post operative stiffness of elbow (decreased elbow extension, pronation and supination) at 6 months follow up. (f) X-ray at 6 months follow-up

X-ray of 32 y/f entrepreneur with Heterotopic ossification at 6 months follow up post operatively with good range of elbow motion in flexion, extension, pronation and supination.

SR. NO	MRD	AGE	Gender	OCCUPATION	MODE OF INJURY	ASSOCIATED INJURIES	DIAGNOSIS (MASON TYPE)	SURGERY APPROACH	DURATION OF SURGERY	BLOOD LOSS (IN ML)
1	109631	50	FEMALE	HOMEMAKER	RTA	LCL MCL	Type IV	KOCHER'S	2HR 10MIN	100ml
2	256524	57	FEMALE	HOMEMAKER	RTA	NONE	Type III	KOCHER'S	1HR 30MIN	30ml
3	1155042	28	MALE	ENGINEER	RTA	LCL MCL #CORONOID	Type IV	KOCHER'S	2HR 40MIN	50ml
4	1194426	42	FEMALE	HOMEMAKER	RTA	NONE	Type III	KOCHER'S	1HR 30MIN	30ml
5	1200323	59	FEMALE	HOMEMAKER	DOMESTIC FALL	#OLECRANON	Type IV	POSTERIOR	2HR 40min	150ml
6	1243321	32	MALE	BUSINESSMAN	RTA	NONE	Type III	KOCHERS	1HR 20min	50ml
7	1282459	65	FEMALE	HOMEMAKER	RTA	LCL	Type IV	KOCHER'S	2HR 20MIN	70ml
8	1286409	54	FEMALE	HOMEMAKER	RTA	NONE	Type III	KOCHER'S	1HR 40MIN	30ml
9	198060	34	MALE	MECHANIC	RTA	LCL	Type III	KOCHER'S	2HR 20MIN	30ml
10	1308921	66	FEMALE	HOMEMAKER	RTA	NONE	Type III	KOCHER'S	1HR 30MIN	30ml
11	1316142	57	MALE	BUSINESSMAN	RTA	#OLECRANON	Type IV	POSTERIOR	2HR 10min	75ml
12	1375842	28	FEMALE	HOMEMAKER	RTA	NONE	Type IV	POSTERIOR	1HR 40MIN	50ml
13	1448439	60	FEMALE	HOMEMAKER	RTA	#OLECRANON	Type III	POSTERIOR	2HR 40MIN	100ml
14	1448688	28	MALE	STUDENT	RTA	NONE	Type III	KOCHER'S	1HR 50MIN	50ml
15	1455754	82	MALE	RETD LABOURER	ASSAULT	LCL	Type IV	KOCHERS	1HR 50MIN	30ml
16	1476558	62	MALE	RETD GOVT EMP	DOMESTIC FALL	NONE	Type III	KOCHER'S	1HR 45MINS	50ml
17	1481721	28	MALE	ENGINEER	RTA	LCL MCL #OLECRANON	Type IV	POSTERIOR	3HR 10MIN	150ml
18	1517853	47	MALE	SHOP OWNER	RTA	#OLECRANON	Type IV	POSTERIOR	2H 45MIN	100ml
19	1522433	45	MALE	PROPERTY DEALER	RTA	LCL MCL #CORONOID	Type IV	KOCHER'S	1H 55 MIN	75ml
20	1635196	32	FEMALE	ENTREPRENEUR	RTA	NONE	Type IV	KOCHER'S	1H 30 MIN	30ml
21	1527965	68	FEMALE	HOMEMAKER	DOMESTIC FALL	#OLECRANON	Type IV	POSTERIOR	2H 30MIN	75ml
22	214277	52	MALE	BUSINESSMAN	RTA	LCL	Type IV	KOCHER'S	1H 50MIN	30ml
23	1570405	25	MALE	STUDENT	RTA	NONE	Type III	KOCHER'S	1H 35MIN	30ml
24	941530	64	FEMALE	HOMEMAKER	RTA	#OLECRANON	Type III	POSTERIOR	2H 20MIN	75ml
25	1571880	42	FEMALE	HOMEMAKER	RTA	NONE	Type III	KOCHER'S	1H 45MIN	30ml
26	1587120	69	FEMALE	HOMEMAKER	DOMESTIC FALL	#OLECRANON	Type III	POSTERIOR	2H 30MIN	75ml

SR. NO	MRD	COMPLICATION	Immediate post op period					
			Elbow flexion (in degrees)	Elbow extension deficit (in degrees)	Supination (in degrees)	Pronation (in degrees)	Pain Score According to MEPS	Motion Arc (in degrees)
1	109631	NONE	65 to 121	65	44	25	Moderate 15	56
2	256524	NONE	70 to 118	70	41	22	Moderate 15	48
3	1155042	NONE	60 to 122	60	50	25	Mild 30	62
4	1194426	NONE	63 to 120	63	43	29	Moderate 15	57
5	1200323	STIFF ELBOW	71 to 102	71	28	20	Severe 0	31
6	1243321	NONE	45 to 130	45	60	46	Mild 30	85
7	1282459	NONE	59 to 120	59	47	34	Mild 30	61
8	1286409	NONE	79 to 118	79	50	28	Moderate 15	39
9	198060	NONE	64 to 117	64	41	33	Moderate 15	53
10	1308921	NONE	62 to 115	62	49	36	Moderate 15	53
11	1316142	NONE	74 to 101	74	43	37	Severe 0	27
12	1375842	NONE	74 to 123	74	39	26	Moderate 15	49
13	1448439	NONE	68 to 112	68	38	30	Moderate 15	44
14	1448688	NONE	52 to 128	52	55	45	Mild 30	76
15	1455754	STIFF ELBOW	82 to 100	82	20	20	Severe 0	18
16	1476558	NONE	68 to 120	68	34	28	Moderate 15	52
17	1481721	NONE	68 to 106	68	40	30	Moderate 15	38
18	1517853	NONE	70 to 110	70	32	24	Moderate 15	40
19	1522433	NONE	60 to 118	60	46	32	Moderate 15	58
20	1635196	HETEROTOPIC OSSIFICATION	78 to 105	78	30	18	Severe 0	27
21	1527965	NONE	82 to 110	82	32	26	Severe 0	28
22	214277	STIFF ELBOW	72 to 108	72	30	26	Severe 0	36
23	1570405	NONE	58 to 122	58	44	34	Moderate 15	64
24	941530	NONE	80 to 100	80	26	24	Severe 0	20
25	1571880	NONE	66 to 116	66	44	27	Moderate 15	50
26	1587120	NONE	82 to 108	82	28	26	Severe 0	26

SR. NO	MRD	Outcome measure								
					Follow up at 3 months					
		Stability Score according to MEPS	ADL Score according to MEPS	Mayo Elbow Performance Score (MEPS)	Elbow flexion (in degrees)	Elbow extension deficit (in degrees)	Supination (in degrees)	Pronation (in degrees)	Pain Score According to MEPS	Motion arc (in degrees)
1	109631	10	10	50	0 to 132	0	88	78	None 45	132
2	256524	10	10	40	10 to 125	10	84	80	None 45	115
3	1155042	10	10	65	0 to 135	0	90	86	None 45	135
4	1194426	10	10	50	2 to 129	2	84	78	None 45	127
5	1200323	10	0	15	16 to 116	16	50	45	Mild 30	100
6	1243321	10	15	70	0 to 142	0	92	90	None 45	142
7	1282459	10	10	65	0 to 134	0	83	76	None 45	134
8	1286409	10	0	30	12 to 127	12	66	62	None 45	115
9	198060	10	10	50	0 to 136	0	84	74	None 45	136
10	1308921	10	0	40	11 to 133	11	69	77	None 45	122
11	1316142	10	0	15	5 to 115	5	60	80	None 45	110
12	1375842	10	0	30	4 to 132	4	74	74	None 45	128
13	1448439	10	5	35	12 to 128	12	68	70	None 45	116
14	1448688	10	10	65	0 to 138	0	88	78	None 45	138
15	1455754	10	0	15	30 to 118	30	30	44	Mild 30	88
16	1476558	10	10	50	5 to 135	5	76	71	None 45	130
17	1481721	10	5	35	8 to 130	8	74	68	None 45	122
18	1517853	10	5	35	10 to 135	10	72	70	None 45	125
19	1522433	10	10	50	5 to 135	5	74	72	None 45	130
20	1635196	10	0	15	20 to 130	20	70	82	Mild 30	110
21	1527965	10	0	15	26 to 128	26	60	62	None 45	102
22	214277	10	5	20	24 to 126	24	58	60	Mild 30	102
23	1570405	10	10	50	18 to 138	18	70	74	None 45	120
24	941530	10	0	15	32 to 122	32	56	56	Mild 30	90
25	1571880	10	5	45	8 to 134	8	78	71	None 45	126
26	1587120	10	0	15	28 to 120	28	58	60	Mild 30	92

SR. NO	MRD												
					Follow up at 6 months								
		Stability Score according to MEPS	ADL Score according to MEPS	Mayo Elbow Performance Score (MEPS)	Elbow flexion (in degrees)	Elbow extension deficit (in degrees)	Supination (in degrees)	Pronation (in degrees)	Pain Score According to MEPS	Motion arc (in degrees)	Stability Score according to MEPS	ADL Score according to MEPS	Mayo Elbow Performance Score (MEPS)
1	109631	10	25	100	0 to 136	0	90	83	None 45	136	10	25	100
2	256524	10	25	100	0 to 132	0	88	80	None 45	132	10	25	100
3	1155042	10	25	100	0 to 135	0	90	86	None 45	135	10	25	100
4	1194426	10	25	100	0 to 130	0	87	81	None 45	130	10	25	100
5	1200323	10	25	85	14 to 124	14	58	48	Mild 30	110	10	25	85
6	1243321	10	25	100	0 t0 142	0	92	90	None 45	142	10	25	100
7	1282459	10	25	100	0 to 134	0	89	79	None 45	134	10	25	100
8	1286409	10	25	100	9 to 128	9	68	60	None 45	119	10	25	100
9	198060	10	25	100	0 to 138	0	84	74	None 45	138	10	25	100
10	1308921	10	25	100	4 to 140	4	70	78	None 45	136	10	25	100
11	1316142	10	25	100	5 to 115	5	62	82	None 45	110	10	25	100
12	1375842	10	25	100	2 to 134	2	74	80	None 45	132	10	25	100
13	1448439	10	20	95	8 to 130	8	74	76	None 45	122	10	25	100
14	1448688	10	25	100	0 to 138	0	90	82	None 45	138	10	25	100
15	1455754	10	15	70	24 to 110	24	45	58	Mild 30	86	10	20	75
16	1476558	10	25	100	5 to 135	5	76	72	None 45	130	10	25	100
17	1481721	10	25	100	8 to 130	8	74	70	None 45	122	10	25	100
18	1517853	10	25	100	5 to 135	5	90	78	None 45	130	10	25	100
19	1522433	10	25	100	0 to 135	0	88	82	None 45	135	10	25	100
20	1635196	10	25	85	10 to 130	10	74	82	None 45	120	10	25	100
21	1527965	10	20	95	14 to 132	14	68	74	None 45	118	10	25	100
22	214277	10	20	80	16 to 135	16	64	68	Mild 30	119	10	25	85
23	1570405	10	25	100	16 to 140	16	72	80	None 45	124	10	25	100
24	941530	10	15	70	15 to 118	15	60	64	Mild 30	103	10	25	85
25	1571880	10	25	100	0 to 134	0	84	78	None 45	134	10	25	100
26	1587120	10	15	70	14 to 124	14	62	66	None 45	110	10	25	100

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(72)

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The Principal
Dayanand Medical College & Hospital
Ludhiana

Subject:: Approval of Plan of Thesis.

This is to inform you that the Faculty of Medical Sciences in its meeting held on 25.09.2023 has approved the plan of thesis of **Shikhar Bindal**, a student of your college for **MS Orthopaedics** along with the names of Supervisor/Co-Supervisor as under:-

Topic Plan of Thesis
Functional outcomes of radial head arthroplasty .

Supervisor	Co-Supervisor:-	Co-Supervisor:-
Dr. Rajnish Garg	Dr. Deepak Jain	Dr. Shekhar Singhal
Prof. & Head,	Professor	Assoc. Professor
Dept. of Orthopaedics,	Dept. of Orthopaedics	Dept. of Orthopaedics

The student may submit the thesis in triplicate alongwith the plan in triplicate also, to the Controller of Examinations, BFUHS, Faridkot, at least six months before the commencement of theory examination, if he/she is otherwise eligible to take the examination. He /She may be directed to attach a photocopy of this letter with the forwarding letter while submitting thesis in the University along with the letter of approval of University for change of supervisor/Co-Supervisor, change of topic, if any.

Controller of Examinations

Note :

1. *If any discrepancy found regarding topic of thesis or Supervisor/Co-Supervisor, inform undersigned within one month after issue of this letter.*

FUNCTIONAL OUTCOMES OF RADIAL HEAD ARTHROPLASTY

THESIS PROPOSAL

FOR APPROVAL OF SUBJECT OF THESIS TO BE SUBMITTED IN

PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MS

In

ORTHOPEDICS

OF THE

BABA FARID UNIVERSITY OF HEALTH SCIENCES

FARIDKOT

DR SHIKHAR BINDAL

AUGUST, 2022

DEPARTMENT OF ORTHOPEDICS
DAYANAND MEDICAL COLLEGE AND HOSPITAL
LUDHIANA

ABSTRACT OF PLAN OF THESIS

Title	Functional outcomes Of Radial head Arthroplasty
For the degree of	MS Orthopedics
Name of the candidate	Dr Shikhar Bindal
Supervisor	Dr. Rajnish Garg, Professor & Head, Department of Orthopedics, DMCH, Ludhiana
Co-Supervisor	Dr. Deepak Jain, Professor, Department of Orthopedics, DMCH, Ludhiana Dr. Shekhar Singhal, Associate Professor, Department of Orthopedics, DMCH, Ludhiana
Institution	Dayanand Medical College and Hospital, Ludhiana
University	Baba Farid University of Health Sciences, Faridkot

Introduction: Through a synergistic relationship between a bony foundation and its surrounding soft tissue, the radial head is an important component that allows for the inherent stable fluidity that lies in the elbow. Also, The radial head plays a critical role in elbow mechanics, transmitting up to 90% of the force across the elbow and acting as an important secondary stabilizer to valgus force.

Radial head injuries occur on a spectrum, from isolated low-energy minimally displaced fractures to the high- energy impacted, comminuted fracture with associated ligamentous and bony injury.

Comminuted fractures of the radial head are challenging to treat with open reduction and internal fixation. Radial head arthroplasty is an alternative treatment with results that compare favorably with those reported after open reduction and internal fixation and it has been advocated for the treatment of un-reconstructible radial head fractures with concomitant medial collateral ligament injury, interosseous ligament injury, or elbow dislocation and for treatment of complications after failed internal fixation or radial head excision.

The bulk of studies on radial head replacement consist of a heterogeneous group of patients, treatments, and outcome measures and no studies were conducted about radial head replacement outcomes in Indian population.

Aim of Study: To evaluate the functional outcome in the immediate post-operative period as well as at 6 months, 1 year and 2 years in patients undergoing radial head replacement

Materials & methods: All the patients scheduled to undergo replacement of the radial head in Dayanand Medical College & Hospital, Ludhiana will be included in the study and evaluated on the basis of elbow flexion, elbow extension deficit, supination, pronation post operative complications and MEPS scores, in the immediate post-operative period, and then at 3 months and 6 months respectively to analyze the functional outcome in patients.

Clinical Significance: Management has evolved over the past few decades as have the techniques and implants used to treat them. There are various surgical treatment options available, including open reduction and internal fixation or radial head replacement. Radial head arthroplasty is an alternative treatment with results that compare favorably with those reported after open reduction and internal fixation of similar fractures.

(Signature)
Candidate

(Signature)
Co-supervisor

(Signature)
Supervisor

(Signature)
Principal

CERTIFICATE OF FACILITIES AVAILABLE

This is to certify that the facilities for work on the subject of thesis titled **"FUNCTIONAL OUTCOMES OF RADIAL HEAD ARTHROPLASTY"** exist in the Department of Orthopedics at Dayanand Medical College and Hospital, Ludhiana and will be provided to the candidate. We will see that the data being included in the thesis are genuine and is collected by the candidate himself under our supervision and guidance.

Supervisor

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Co-Supervisor's

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Place: _____

Date: _____

APPROVAL PROFORMA
BY
RESEARCH & ETHICAL COMMITTEE
DAYANAND MEDICAL COLLEGE & HOSPITAL, LUDHIANA

Name of candidate	Dr Shikhar Bindal
Department	Orthopedics
Topic of Thesis	Functional Outcomes Of Radial head Arthroplasty
Likely date of appearing in PG examination	May/ June , 2024
Date of enrollment	04/02/2022
Name of Head of Department	Dr Rajnish Garg
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Signature of Members of Research Committee with Stamp	**Signature of Members of Ethics Committee with Stamp**
Dr. Harpreet Kaur (Professor & Head, Pathology)	Mr. R K Sharma (Legal Expert)
Dr. Jaspal Singh (Professor & Head, Surgery)	Dr. Ramit Mahajan (Associate Professor, Gastroenterology)
Dr. Dinesh Gupta (Professor & Head, Medicine)	Dr. Anu Sharma (Professor, Anatomy)
Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)	Dr. Sandeep Kaushal (Dean Academics & Professor & Head, Pharmacology)
Dr. Gurpreet S Wander (Vice Principal)	Dr. Gurpreet S Wander (Vice Principal & Professor & Head, Cardiology)
	Dr. Gagandeep Singh (Secretary, Ethics Committee Professor & Head, Neurology)

Approved: Yes / No

Dr. Sandeep Puri
Chairperson
Research Committee

Chairperson
Research Committee

Approved: Yes / No

Prof. Arvind Malhotra
Chairperson
Ethics Committee

Chairperson
Ethics Committee

BABA FARID UNIVERSITY OF HEALTH SCIENCES, FARIDKOT

PROFORMA FOR REGISTRATION OF SUBJECT FOR DISSERTATION

1	NAME OF THE CANDIDATE AND ADDRESS	DR SHIKHAR BINDAL, PG HOSTEL ROOM NO N 32, DMCH CAMPUS, LUDHIANA, PUNJAB
2	NAME OF THE INSTITUTE	Dayanand Medical College and Hospital, Ludhiana
3	COURSE OF STUDY AND SUBJECT	04/02/2022
4	DATE OF ADMISSION OF COURSE	MS ORTHOPEDICS
5	TITLE OF THE TOPIC	Functional outcomes Of Radial Head Arthroplasty

6. BRIEF RESUME OF THE INTENDED WORK

6.1 NEED FOR THE STUDY

Elbow fractures account for approximately 5% of all sustained fractures. Of those cases, radial head fractures account for about one third, making up a significant portion of elbow injuries.[1] This relatively high incidence rate, along with a mean affected patient age of 45 years, has the potential to negatively impact a large portion of the young, active patient population.

The surgical treatment of comminuted radial head fractures (modified Mason types III and IV) is challenging and controversial. Surgical treatment options include open reduction and internal fixation (ORIF), radial head resection (RHR) and radial head arthroplasty (RHA). It has been noted that Radial head arthroplasty results compare favourably with those reported after open reduction and internal fixation.[2] However, there is still no clear advantage of one over the other.[3-5] Radial head excision was advocated for the treatment of displaced radial head fractures in the past, but it has fallen out of favour as a result of complications such as valgus elbow instability, elbow stiffness, and proximal migration of the radius.[6]

RHA has been advocated for the treatment of un-reconstructible radial head fractures with concomitant medial collateral ligament injury, interosseous ligament injury, or elbow dislocation and for treatment of complications after failed internal fixation or radial head excision.[7,8]

Previous systematic reviews and meta-analyses reported treatment outcomes of ORIF and RHA. The first meta-analysis reported that the appropriate surgical treatment of radial head and neck fractures was dependent upon the Mason classification (ORIF in type II and RHA in types III–IV).[9] Most meta-analyses report that RHA results in better elbow function and fewer adverse events than ORIF for Mason type III fractures for short-term outcomes. However, this evidence is of low quality and The bulk of studies on radial head replacement consist of a heterogeneous group of patients, treatments, and outcome

measures.[10-13] These series do not differentiate between acute or delayed treatment of the injury, isolated radial head fractures or those combined with associated injuries, or use of different implants. Further no studies have been conducted about radial head replacement outcomes in Indian population.

Several parameters must be taken into account in order to select the best treatment option for mason type III and IV radial head fractures. These include fracture stability, displacement, articular involvement, and the presence of associated forearm or elbow injuries. Treatment decisions may be guided, but not strictly based on, classification systems.

The Mason classification system attempts to classify treatment options however Treatments of Mason type III fractures are more controversial. Non- operative treatments yield unsatisfactory results. Fragment excision is rarely indicated; if fragments involve less than 25% of the surface area of the radial head, they may be removed without replacement if elbow stability is not compromised. In Mason type III fractures where reduction and internal fixation is not feasible, radial head replacement is indicated. Fractures with three or more pieces treated with ORIF may develop unpredictable ulno-humeral and forearm motion, as well as failure of fixation, fragment nonunion, and osteonecrosis.[14,15]

The use of metal radial head prosthesis to help stabilise an elbow is appealing because internal fixation of multi- fragment, displaced fractures of the radial head is susceptible to early or late failure. Debate over the treatment of Mason type III fractures still exists. Radial head replacement has been associated with improved patient satisfaction, decreased complications, and better results than ORIF.[15]

The aim of the current study is to provide sufficient data to evaluate the outcomes in a closely followed cohort of patients in whom an un-reconstructible radial head fracture has been treated with a modular

metallic prosthesis**.** Since it would involve functional outcomes in Indian populations it will help provide data on the implications of radial head replacement in the population and subsequently help improve surgical management of radial head fractures within the Indian population.

6.2 REVIEW OF LITERATURE

Radial head fractures are common injuries, and there is little information on the reliability of classification systems for such injuries. David M. Sheps et al compared The inter observer reliability of classification systems for radial head fractures and found out that the Hotchkiss modification of the Mason classification system is substantially successful at differentiating between fractures that require operative treatment and those that do not.[16]

In general, the treatment of undisplaced non comminuted Mason typeIfractures is conservative with a pressure bandage and sling for support, and active mobilization as early as possible.

Treatment options for mason type iii and iv still remain controversial and K. Chaijenkij et al performed a systematic review to assess clinical outcomes after internal fixation, arthroplasty and resection for treatment of comminuted radial head fractures. He observed that ORIF could have an approximately 2.75 times higher risk of complications when compared to RHA in the treatment of comminuted radial head fracture.[17]

For the treatment of comminuted, displaced fractures however, Mason originally advised to perform a resection of the comminuted fractured radial head, numerous other surgical techniques have been described last decades. In cases of isolated comminuted radial head fractures, without associated instability of the elbow, resection of the radial head may lead to satisfactory results. Replacement of the radial head by silicone implants was performed with the idea to restore elbow stability, but resulted in several implant-related problems and complications. Subsequently, management by ORIF became more popular. Good results were reported after ORIF for stable radial head fractures. However, Ring et al established that ORIF for Mason type III fractures with more than three articular fragments was more likely to result in unsatisfactory outcomes compared to fractures with only 2 or 3 simple fragments.[14] These severely comminuted unstable fractures of the radial head are difficult to restore and are prone to result into hardware failure or nonunion. Moro et al therefore advised to use metallic radial

head prosthesis (RHP) if a stable internal fixation of the comminuted radial head cannot be achieved.

A randomized study by Chen et al, which compared ORIF *vs* arthroplasty for comminuted unstable radial head fractures revealed that after two years of follow-up patients in the replacement group had significantly better PROMs. Furthermore, more complications (limitation in motion, nonunion, malunion, HO, infection) were seen following ORIF compared to arthroplasty. The authors concluded that replacement is more effective than ORIF in clinical practice. However, they justly noted that prosthesis have problems with ageing, loosening and wear, which are not seen in the short-term follow-up of that study.[18]

Lindenhovius et al reported on the long-term outcome of ORIF for stable displaced partial articular fractures of the radial head with an average 22 years follow-up. Although the results were good, complications were seen in 44% of patients.[19]

Ruan et al. compared open reduction and internal fixation with radial head replacement for 22 patients with Mason type III fractures. Of these patients, 14 were treated with bipolar metal head prosthesis and 8 were treated with open reduction and internal fixation. Notably, the results were good to excellent in 92.9% of prosthesis replacement patients and only in 12.5% of ORIF patients.[15]

Harrington et al. performed a long-term review of 20 patients with mean follow up of 12.1 years. They found results that were excellent in 12 patients, good in 4 patients, fair in 2 patients, and poor in 2 patients. Their results suggest that this construct functions well on a long-term basis.[12]

For assessment of functional outcomes following radial head replacement Mayo Elbow Performance Score (MEPS) and range of motion (ROM) have been reported to be superior following acute radial head arthroplasty compared with delayed reconstruction; however, other studies by Brinkman JM et al, Chapman CB et al, Harrington et al report no difference or do not directly compare the 2 groups.[12,15]

Elbow function post-operatively can be assessed using a variety of tools of which self-reported questionnaire-based scoring systems such as upper extremity disability (disabilities of the arm shoulder and hand questionnaire {DASH}) and patient rated elbow evaluation (PREE) and American shoulder and elbow surgeons (ASES) report form are some of the most convenient methods to ensure compliance and follow-up.
Mayo Elbow Performance Index (MEPI) score (an elbow impairment and functional index) and Grip strength and range of motion testing can be performed using NK hand evaluation system. The LIDO work-set can be used for isometric testing of elbow flexion, extension, pronation and supination strength for assessing elbow function.

6.3 AIMS AND OBJECTIVES OF THE STUDY

To evaluate the functional outcomes in the immediate post-operative period as well as at three and six months in patients undergoing radial head replacement.

7.0 MATERIALS AND METHODS

7.1SOURCE OF DATA

All the patients scheduled to undergo replacement of the radial head in Dayanand Medical College & Hospital, Ludhiana will be initiated for the study and evaluated on the basis of elbow flexion, elbow extension deficit, supination, pronation post operative complications and MEPS (Mayo Elbow Performance Scores), in the immediate post-operative period, at 3 months and then at 6 months respectively to analyse the functional outcome in patients.

7.2 METHOD OF COLLECTION OF DATA

It will be prospective and retrospective hospital based study over period of 32 months between January 2021 and August 2023, Information will be written in the proforma attached.

Inclusion criteria

-All patients presenting with radial head fractures planned for radial head arthroplasty will be included in the study

-All patients undergoing radial head arthroplasty using metallic head implant prosthesis (cobalt chromium and titanium head implants)

-Patients undergoing radius head arthroplasty by any surgical approach (posterior, medial, lateral, anterior or global approaches)

Exclusion criteria

- Any patient not giving consent would be excluded
- Any patient below the age of 18 years or with incomplete fusion of epiphysis
- Any patient with radial head fracture planned for open reduction and internal fixation or radial head excision would be excluded from the study

-Any patient with pre existing prosthesis or metal work insitu

Duration of study/number of cases: this study will be done over 2.5 years.

STUDY DESIGN: retrospective and prospective hospital based study of outcomes will be conducted in Dayanand medical college and hospital, which is tertiary care, referral hospital of North India. The study will be over a period of 32 months from January 2021 to August

2023. All patients sustaining scheduled to undergo replacement of the radial head who were admitted to DMCH during the study period will be enrolled. Standard predesigned structured proforma will be filled in direct interview with patient.

OUTCOME:

Post operative functional outcomes will be measured using outcome measurements in the immediate post operative period, at 3 months and at 6 months respectively

Outcome measure	Score and P value (immediate post op period)	Score and P value (follow up at 3 months)	Score and P value (follow up at 6 months)
Elbow flexion			
Elbow extension deficit			
Supination			
Pronation			
Mayo Elbow Performance Score (MEPS)			

In adults, a functional motion arc of 30 to 130 degrees of elbow flexion and 50 degrees of pronation to 50 degrees of supination is well established. Degree of elbow flexion, degree of extension deficit, degree of pronation, degree of supination will be measured in patients of radial head replacement post operatively, at 3 months and at 6 months using a goniometer.

Mayo Elbow Performance Score (MEPS)- The Mayo Elbow Performance score (MEPS) or Mayo Elbow Performance Index (MEPI) is an instrument used to test the limitations, caused by pathology, of the elbow during activities of daily living. This specific test uses 4 subscales:

1. Pain,
2. Range of Motion
3. Stability
4. Daily Function

MEPS is a 4 part test where clinical information is rated based on a 100 points scale.

- <60 - poor
- 60-74 – fair
- 75-89 - good
- 90-100 – excellent

For pain-

- 45 points are for patients who do not have pain,
- 30 points are given to patients who have mild pain,
- moderate pain results in 15 points,
- patients with severe pain get 0 points.

For range of motion-

The patient starts with his elbow fully extended and then tries to flex the elbow.

- 20 points are given when the arm reaches more than 100° flexion,
- 15 points If the angle is between 100°-50°
- 5 Points when the elbow bends 50° or less

For Stability-

- When the elbow is considered stable 10 points are given.
- A mildly unstable elbow results in 5 points.
- An unstable elbow does not receive points (0).

For Daily Function

Each activity is given 5 points and it is assessed how well the patient is able to participate in activities of daily life. The activities are:

- Combing your hair
- Performing personal hygiene

- Eating
- Putting on shirt and shoes.

The final MEPS score will be used as a measurement of functional outcome in patients of radial head replacement post operatively, at 3 months and at 6 months respectively.

STATISTICAL ANALYSIS:

Data will be described in terms of range; mean ±standard deviation (± SD), median, frequencies (number of cases) and relative frequencies (percentages) as appropriate. To determine whether the data is normally distributed, a Kolmogorov-Smirnov test will be used. Comparison of quantitative variables will be done using Paired t-test and Wilcoxon rank test for independent samples for parametric and non-parametric data respectively. A probability value (p value) less than 0.05 will be considered statistically significant. All statistical calculations will be done using (Statistical Package for the Social Science) SPSS 21version (SPSS Inc., Chicago, IL, USA) statistical program for Microsoft Windows..

7.3 DOES THE STUDY REQUIRE ANY INVESTIGATIONS OR INTERVENTIONS TO BE CONDUCTED ON PATIENTS OR OTHER HUMANS OR ANIMALS? IF SO, PLEASE DESCRIBE BRIEFLY.

Surgical intervention being performed on humans- The procedure is performed under general and/or regional anaesthesia. An incision is made and the elbow joint is exposed. The fragments of bone are removed. The neck of the radius is prepared and a radial head prosthesis is inserted. Any damaged ligaments are repaired. At the end of the procedure, soft tissue closure is done with sutures.

7.4 HAS ETHICAL CLEARENCE BEEN OBTAINED FROM YOUR INSTITUTION IN CASE OF 7.3?

Yes, attached herewith.

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PROFORMA

A performa will be filled at the start of the study for patients at the time of admission-

SNO:

AGE/SEX:

NAME:

ADMISSION NO:

MRD NO: DATE OF SURGERY:

DATE OF ADMISSION: DATE OF DISCHARGE:

RELIGION:

OCCUPATION:

DIAGNOSIS:

SURGERY:

APPROACH:

DURATION OF SURGERY:

BLOOD LOSS-

Signature of Candidate **Signature of Supervisor**

Expected:

Observed:

COMPLICATION (if any)

Outcome measure	Score and P value (immediate post op period)	Score and P value (follow up at 3 months)	Score and P value (follow up at 6 months)
Elbow flexion			
Elbow extension deficit			
Supination			
Pronation			
Mayo Elbow Performance Score (MEPS)			

Signature of Candidate **Signature of Supervisor**

INFORMED PATIENT CONSENT

Date: _____

I…….D/o, W/o, S/o……..…… am willing to participate in the study **"FUNCTIONAL OUTCOMES OF RADIAL HEAD ARTHROPLASTY"** The procedure with its complications has been explained to me in local vernacular language. I have fully understood that no special tests and extra expenditure in any form, merely for the purpose of thesis is being carried out. I am free to opt out the study any time without assigning any reason.

……. ……
Signature of the Witness Signature of the patient

Name:

Signature of Candidate **Signature of Supervisor**

मरीज अनुमति फार्म

तिथि _____

मैं _____ पत्नी/पुत्र/पुत्री _____
निवासी _____
इस शोधकार्य "**FUNCTIONAL OUTCOMES OF RADIAL HEAD ARTHROPLASTY"** में भाग लेने के लिए सहमत हूँ। मैं इस शोधकार्य में भाग लेने के लिए अपनी स्वेच्छा से तैयार हूँ। मैं पुष्टि करता/करती हूँ की यह स्वीकृति देने के लिए मुझे कोई आर्थिक प्रलोभन नहीं दिया गया और न ही दबाव डाला गया है। मुझे इस शोधकार्य का उद्देश्य स्पष्ट कर दिया गया है और मुझे यह विश्वास है की यह विज्ञान और मानवता के लाभ के लिए है। मुझे इस शोधकार्य में होने वाले जोखिम के बारे में समझा दिया गया है और मेरी समझ में यह जोखिम बहुत मामुली है।

मैं इस शोधकार्य में भाग लेने के सम्बन्ध में किसी भी समय अपनी अस्वीकृति व्यक्त कर सकता/सकती हूँ और मेरे अस्वीकृति व्यक्त करने का मेरे इलाज पर कोई प्रभाव नहीं पड़ेगा।

_____ _____
गवाह के हस्ताक्षर रोगी के हस्ताक्षर/अंगूठे का निशान
नाम: नाम:

_____
अन्वेषक के हस्ताक्षर

_____
विद्यार्थी के हस्ताक्षर

ਮਰੀਜ਼ ਰਜ਼ਾਮੰਦੀ ਫਾਰਮ

ਮਿਤੀ_____

ਮੈ_____ਪਤਨੀ/ਪੁੱਤਰ/ਪੁੱਤਰੀ_____

ਵਾਸੀ _____

“FUNCTIONAL OUTCOMES OF RADIAL HEAD ARTHROPLASTY” ਤੇ ਚਲ ਰਹੀ ਖੋਜ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਰਜ਼ਾਮੰਦ ਹਾਂ। ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਲਈ ਮੈ ਆਪਣੀ ਮਰਜ਼ੀ ਨਾਲ ਤਿਆਰ ਹਾਂ। ਮੈ ਇਹ ਦਸਣਾ ਚਾਹੁੰਦਾ ਹਾਂ/ ਚਾਹੁੰਦੀ ਹਾਂ ਕੇ ਇਹ ਰਜ਼ਾਮੰਦੀ ਦੇਣ ਵਾਸਤੇ ਮੈਨੂ ਕਿਸੇ ਵੀ ਤਰਾਂ ਦਾ ਲੋਭ-ਲਾਲਚ ਨਹੀ ਦਿੱਤਾ ਗਿਆ ਅਤੇ ਨਾ ਹੀ ਕੋਈ ਦਬਾ ਪਾਇਆ ਗਿਆ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਦਾ ਮਨੋਰਥ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਭਰੋਸਾ ਦਵਾਇਆ ਗਿਆ ਹੈ ਕੇ ਇਹ ਖੋਜ ਵਿਗਿਆਨ ਅਤੇ ਮਾਨਵਤਾ ਦੀ ਭਲਾਈ ਲਈ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਵਿਚ ਹੋਣ ਵਾਲੇ ਖਤਰੇ ਬਾਰੇ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ ਅਤੇ ਮੈਨੂ ਇਹ ਯਕੀਨ ਹੈ ਕੇ ਇਹ ਖਤਰਾ ਬਹੁਤ ਮਾਮੂਲੀ ਹੈ। ਮੈਨੂ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਦਾ ਢੰਗ – ਤਰੀਕਾ ਸਮਝਾ ਦਿੱਤਾ ਗਿਆ ਹੈ।

ਮੈ ਇਸ ਖੋਜ ਕੰਮ ਵਿਚ ਹਿੱਸਾ ਲੈਣ ਬਾਰੇ ਆਪਣੀ ਰਜ਼ਾਮੰਦੀ ਕਿਸੇ ਵੀ ਸਮੇ ਵਾਪਸ ਲੈ ਸਕਦਾ ਹਾਂ/ ਸਕਦੀ ਹਾਂ ਅਤੇ ਮੇਰੀ ਰਜ਼ਾਮੰਦੀ ਵਾਪਸ ਲੈਣ ਦਾ ਮੇਰੇ ਇਲਾਜ ਤੇ ਕੋਈ ਅਸਰ ਨਹੀ ਹੋਵੇਗਾ।

_____ _____

ਗਵਾਹ ਦੇ ਹਸਤਾਖਰ ਮਰੀਜ਼ ਦੇ ਹਸਤਾਖਰ

ਮਿਤੀ_____ ਮਿਤੀ_____

ਪਤਾ _____ ਪਤਾ _____

_____

ਨਿਰੀਖਕ ਦੇ ਹਸਤਾਖਰ

_____

ਸਿਖਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ